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THE
# LARYNGOSCOPE.

VOL. LVII JANUARY, 1947. No. 1

## A REVIEW OF THE AVAILABLE LITERATURE ON THE PHARYNX AND PHARYNGEAL SURGERY FOR 1945.*

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### INNERVATION.

Sprague[1] made a comparative anatomic study on pharyngeal innervation in the rhesus monkey and the primates Tupaia and Tarsius. It is shown that primates and other mammals do not have a pharyngeal plexus as in man, as commonly assumed.

The pharynx in man receives its innervation through the pharyngeal plexus formed by pharyngeal branches of the glossopharyngeal and vagus nerves and by laryngeal branches from the superior cervical ganglion. Ascending and descending branches are given off the plexus to the palate and esophagus respectively. The superior laryngeal nerve may contribute an external branch to the inferior constrictor muscle.

Although in primitive forms the pharyngeal ramus of either the IXth or Xth nerves may be absent and the superior laryngeal nerve contributes important anastomotic branches to the pharyngeal plexus, this tendency is seen less and less as more specialized forms are studied, the superior laryngeal nerve becoming dissociated from the pharyngeal rami of the

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IXth and Xth nerves, which are now constant and distinct entities. The exterior branch of the superior laryngeal nerve is found to contribute frequently to the innervation of the inferior constrictor and also to anastomose with the pharyngeal plexus, so that phylogenetically it can be said to contribute to the plexus.

A definite middle branch of the superior laryngeal nerve and a poorly developed pharyngeal plexus distinguish the pharyngeal innervation of the rhesus monkey from man. In the macaque, pharyngeal and palatine motor fibres leave the medulla by the bulbar accessory and lower vagus roots, passing to the pharyngeal muscles through the pharyngeal ramus of the vagus. The fibres to the stylopharyngeus and ceratohyoid muscles, which are of glossopharyngeal origin, are in some cases distributed through the lingual ramus of this nerve. In Tupaia and Tarsius, glossopharyngeal motor fibres have been found leading to the middle and superior constrictors from the brain stem. It would seem that a trend of increasing plexus formation of pharyngeal nerves is present in primates and rhesus monkeys, culminating in man.

## PATHOLOGY.

Hollender and Szanto[2] studied either grossly or microscopically, or both, 131 specimens of the nasopharynx removed from adults in an attempt to determine the incidence of hyperplasia of the nasopharyngeal or the tubal tonsils, or both. Hyperplasia of the tubal tonsil was found less frequently than hyperplasia of the nasopharyngeal tonsil. Partial involution of the nasopharyngeal tonsil was commonly noted. They found a frequent incidence of hyperplasia of the nasopharyngeal or the tubal tonsils, or both, in adults, especially in older persons.

Hyperplasia of the nasopharyngeal tonsil in adults does not necessarily produce symptoms, but may in the presence of infection or if the vault is large. Unilateral or bilateral hyperplasia of the tubal tonsils may cause impairment of hearing. There seems to be no correlation between hyper-

plasia of the nasopharyngeal lymphoid tissue and general pathologic conditions.

Hollender and Szanto do not attempt to answer the question posed as to the function of the lymphoid tissue but they believe that the fact that nasopharyngeal lymphoid tissue commonly recurs after attempted complete removal suggests that it possesses some definite function.

Baker[3] has classified the status of the lymphoid tissue into four groups: Type 1 designates those cases with no demonstrable lymphoid tissue about the Eustachian tube; Type 2 includes cases with minimal amounts of demonstrable lymphoid tissue about the tubes; Type 3 shows a moderate amount of this tissue about the tubes; and Type 4 is characterized by considerable lymphoid tissue, occasionally the presence of adhesion bands and the narrowing of the orifice of the Eustachian tubes. These four types are diagrammatically sketched.

In these cases Baker does the usual adenoidectomy, when necessary. If indications warrant, this is followed by passage of the forefinger to the pharynx, then to the nasal pharynx to identify and hug the tube and with moderate pressure readily break away any lymphoid tissue and bands about the tube. Baker cautions against the use of the curette because of the danger of injury to the Eustachian tubes. The operation is done under local anesthesia, preferably when the tonsil is removed.

Baker reports five cases and concludes that the "results obtained in 75 cases done to date have been very good and warrant future consideration."

## BACTERIOLOGY.

In a previous study, Rosenow, Mousel and Lundy[4] expressed the opinion that clinical or subclinical infection by a highly specific neurotropic type of alpha-streptococcus may cause convulsions which sometimes occur during general anesthesia. In a lengthy article they describe their method of further study of this problem and the experimental work carried on. Nasopharyngeal cultures were obtained from

patients in whom muscular spasm developed during general anesthesia. In all cases a green producing streptococcus of highly specific properties was isolated and inoculation of these fresh, and also dead, streptococci and filtrates of actively growing cultures into rabbits, guinea pigs and monkeys produced a high incidence of tremors and muscular spasms. They concluded that a neurotoxin produced by a highly specific neurotropic streptococcus during clinical infection of the respiratory tract contributes to the cause of muscular spasms during general anesthesia. Fortunately, intravenous injection of very small amounts (3 cc.) of a 2.5 per cent solution of pentothal sodium usually suffices to control the spasm.

Sulfonamides exert considerably greater retarding effect on the development of bacteria than viruses. Julianelle and Siegle[5] conducted experimental work on 60 children under constant observation and similar environment. The most striking observation reported from the continuous administration of sulfadiazine over a six months' period to physically normal children was a rapid disappearance of Gram-negative cocci from the nasopharynx. The sequence of events observed was first the actual disappearance of Neisseriae from the majority of treated individuals and then the gradual return in spite of doubling the dosage of sulfadiazine. Under prolonged sulfadiazine administration in physically normal children, pneumococcal types may acquire a high degree of resistance to the drug.

## DISEASES.

In routine examination of the nose and throat, too often a thorough examination of the nasopharynx is neglected. Kline[6] points out that the nasopharyngeal space can be thoroughly inspected either through the nose or through the mouth with special instruments if the difficulties of introducing these instruments are overcome and skill is attained in recognizing the varying pictures presented by the different methods of examination. The normal nasopharynx presents considerable anatomic variation when seen with reflected light, with the postnasal mirror and through the lens of the nasopharyngo-

scope. Kline first inspects through the anterior part of each naris with reflected light, then uses the Holmes nasopharyngoscope and, finally, if these are not satisfactory and if there are symptoms and signs of nasopharyngeal disease, he elevates the soft palate and retracts it sufficiently to visualize the nasopharyngeal area directly and with the postnasal mirror. The methods of examination are described in detail. By the use of these methods many important pathologic conditions may be uncovered.

Clinical evidence has demonstrated that the hemolytic streptococcus is occasionally sulfonamide resistant; with this in mind, Plummer and associates[7] instituted a study of cases of pharyngotonsillitis caused by this organism. Only the severer cases were included in this study and a comparable group was used as controls. Complete serology and daily cultures from the tonsils and pharynx were obtained. The response to 15,000 units of penicillin every four hours was most satisfactory. Improvement was noted eight to 10 hours after administration of penicillin. In 24 hours the bacteriologic change was impressive, in that few or no cultures of hemolytic streptococci were obtained from the nasopharynx; however, if therapy was discontinued, there was a rapid return of the hemolytic streptococci. Penicillin therapy, when given over a period of five or six days, effectively controlled the existing infection. A most convincing demonstration of the efficacy of penicillin is to contrast the 24-hour culture of a treated patient with the initial culture when this has shown a heavy growth of hemolytic streptococci. Of 25 such cases, 21 were negative, three were slightly positive, and in only one was the blood plate of the 24-hour culture appreciably positive. This study reveals further evidence of the high antihemolytic streptococcic action of penicillin and emphasizes its value in dangerous hemolytic streptococcic infections.

Cone[8] reports four cases of acute infections of the ear, nose and throat treated by local infiltration with penicillin. He has found intravenous, intramuscular and subcutaneous injections of penicillin of great value in such cases and has been able to obtain a high local concentration of penicillin

by local infiltration than by other routes. There were no untoward reactions to the penicillin in his cases. During a three-month period the author used penicillin as a prophylactic local infiltration just before tonsillectomy in 21 patients, and in 28 patients, only the routine local tonsillectomy was done. Solutions were made in physiologic sodium chloride and contained 5,000 units per cc. From 1 to 2 cc. were used as a deep peritonsillar injection after infiltration with procaine hydrochloride. No reactions occurred and healing was facilitated.

Pike[9] found that small numbers of hemolytic streptococci could be isolated more often from mixtures of throat organisms by culturing the mixtures in a sodium azide crystal violet broth for 24 hours prior to plating than by plating directly from the mixtures. If 0.1 per cent or more of glucose is added to enrichment broth, the chance that streptococci will survive 24-hour incubation is reduced. Blood broth containing sodium azide gradually loses its bacteriostatic power on standing. Of 131 throat swabs from normal children cultured in sodium azide-crystal violet broth, the observed incidence of hemolytic streptococci was increased from 12 to 39 per cent, and of group A streptococci from 5 to 20 per cent.

The bacteriostatic effectiveness of the sulfonamide drugs is well established and when maintained at the wound site in sufficient concentration, the sulfonamides are efficient in controlling certain types of infections. Fox and associates[10] studied the effects of sulfathiazole chewing gum on certain oropharyngeal infections. Particularly interesting are the pictures presented by those conditions in which the beta-streptococci are so frequently the preponderant offending organism. These include acute follicular tonsillitis, acute lymphoid pharyngitis, and the Plaut-Vincent type of ulcerative gingivitis and stomatitis. The specificity of sulfathiazole for the streptococcus probably accounts for the very rapid alleviation of this condition by the chewing of sulfathiazole gum. Fox and associates concluded that from the standpoint of minimal systemic toxicity and maximal local antibacterial potency, sulfathiazole chewing gum is excellent for local oral

and pharyngeal infections; however, best clinical results are obtained in those conditions of the mouth and pharynx in which the beta-hemolytic streptococcus is the predominant organism.

In over 200 patients with acute pharyngitis and tonsillitis treated by a gargle of a 5 per cent solution of sodium sulfathiazole sesquihydrate every two hours, rapid diminution of swelling of the tonsil was observed with early disappearance of exudate when this was present. Although it is difficult to control the results of therapy in such patients, Wiesel and Teague[11] believe that by this treatment symptoms were relieved and the period of disability was shortened. The only complication of treatment in the entire series was a drug reaction which occurred in one patient.

Experiments performed to determine the extent of sulfathiazole absorption seemed to indicate "that the gargle procedure is accompanied by a minimum of absorption of sulfathiazole and consequently would be expected to produce a minimum of toxic reaction."

Advantages of treatment are minimum drug absorption, low toxicity, simplicity and cheapness. Among the disadvantages are disagreeable taste; slight possibility of drug reaction; and if the gargle is used too often, the continuous contact of the solution with the mucous membrane of the pharynx might be injurious.

From a study of the information regarding the reporting of Vincent's infection in 20 of the 22 state health departments where the disease is reportable, it was found that the disease is poorly reported, and Sebelius[12] concluded that there should be a clearer understanding as to the clinical picture that the disease presents. The disease is inaccurately reported since physicians report it as Vincent's infection, and dentists as gingivitis. Sebelius emphasizes the importance of a better understanding of the entire clinical picture as well as of the epidemiological and bacteriological aspects of the disease.

Hampp[13] presents a method for the isolation and cultivation of certain of the oral spirochetes associated with lesions

in cases of Vincent's infection. A well is used for holding the spirochetal-containing inoculum in the confines of a highly nutritious medium of low agar concentration, which favors rapid multiplication and penetration of the medium by the spirochetes. The stained smear was found to be unreliable for identification of the oral spirochetal species.

Hamilton[14] points out that lupus in the pharynx is usually secondary to nasal lupus. The site of most frequent occurrence is the soft palate, the uvula and edges of the faucial pillars being most often involved. Although lesions are rarely seen in the nasopharynx or on the posterior pharyngeal wall, not uncommonly scarring is found in these areas and it is felt that this may be due to former ulceration. This relationship is interesting in that a significant number of removed adenoids in children show evidence of tuberculosis, as do the retropharyngeal glands. Tubal lupus appears to be rare.

Symptomatically, a sense of "something in the throat" is present in pharyngeal lupus. Nodule formation occurs, is frequently extensive and tends toward fibrosis. When ulceration develops, shallow excoriations studded with tubercles and surrounded by varying amounts of scarring are found. Healing results in atrophy of the mucous membrane with associated contracture.

Occasionally a small nodule may be excised if a wide area of apparently normal tissue can be sacrificed with the lesion. The author feels, however, that the treatment of choice is the permanganate method of M. Auregan (1926). The base of the lesion is infiltrated with 2 per cent percaine, followed by complete removal by curettage of the granulations. Finely powdered potassium permanganate is packed into the wound and rubbed in thoroughly with the gloved finger. The crust which then forms comes away in a few days, leaving a healing surface. Although recurrence is not the rule, regular inspection should be carried out for years. In cases treated in this way there is much less later development of fibrosis than in lesions left unattended.

Eliseht[15] reports an illustrative case of phlegmasia of the masticator space with lateral peritonsillar phlegmon of escat

and presents a consideration of the physiologic anatomy of the masticator space, which he thinks is necessary in order to interpret the pathogenesis of certain disturbances in this region. It has been shown by injection experiments that the temporal and masseter regions communicate with each other. Among structures included in this space are the space of Calas and the canal of Constantini. Infection may enter through wounds, foreign bodies or from the lower teeth. The local symptoms of phlegmasia include trismus, pain, sialorrhea and stomatitis and, most important of all, swelling. The condition must be differentiated from phlegmasia of dental or maxillary origin. The prognosis is good unless the infecting agent is very virulent. If the condition is treated early, it can be controlled by the sulfonamides or penicillin and operation is necessary only in cases which have been neglected.

Rothbard[16] describes a method by which it is possible to demonstrate accurately type-specific antibodies, by indirect bacteriostatic test, in sera from human adults convalescing from Lancefield's group A streptococcal infection of the nose and throat. Studies on three patients are reported, the time of appearance of the antibodies varying from three to five weeks. In two of the patients the antibodies persisted for at least 37 weeks after the onset of infection.

A report is made of an exhaustive study of a food-borne epidemic of tonsillitis and pharyngitis caused by beta hemolytic streptococci of group A, type 5, occurring in 100 members of two companies of an air-borne infantry regiment stationed at Fort Bragg, N. C., in November, 1945.[17]

The probable vehicle of infection was thought to have been creamed eggs contaminated during preparation. The illnesses were mild to moderately severe and did not differ appreciably from air-borne infections of the pharynx due to other types of streptococci encountered at the same post. Pharyngeal and tonsillar exudate, or either of these alone, was present in 90 per cent of the cases.

Alternate patients were treated with sulfadiazine sufficient to give high therapeutic blood levels, but no worthwhile benefit

from the standpoint of practical therapeutics was derived from this agent in this epidemic. Suppurative complications were few. Three cases of acute rheumatic fever were proved definitely; two others were suspected, and four others had unexplained febrile relapses of one to four weeks' duration. Four other patients who were symptomatically well showed transient electrocardiographic changes of uncertain meaning, suggesting rheumatic myocarditis. One case had a probable exacerbation of chronic glomerulonephritis.

Eighty-five per cent of the patients showed a significant rise in titer of antistreptolysin or antifibrinolysin during convalescence; 12 per cent more had a very slight rise in titer of antistreptolysin.

The relationship between the presence or absence of tonsils and streptococcal parasitism was confirmed. Patients whose tonsils had previously been removed showed less confluent exudate and less streptococci on culture, and were able to rid themselves of the organisms sooner. Tonsillectomized patients tended to have lower initial levels of antistreptolysin and higher convalescent titers than patients with tonsils.

MacGregor and Long[18] repeated some of their previous experiments on the use of penicillin pastilles in oral inflammation in order to estimate the amount of penicillin likely to reach affected areas at the back of the mouth. Fifty volunteers were used. Instead of penicillin (500 units) the pastilles used were in a gelatin base and contained 1 per cent of methylene blue; the pastilles were placed in the buccal fold between the cheek and the teeth and allowed to dissolve without agitation; the mouths were then examined at five minutes and again at 15 minutes after insertion.

The results indicated "that with a gelatin base, dyes reached the tonsillar area to a sufficient extent to suggest that drugs administered in the same type of base should reach the tonsils in the great majority of cases." MacGregor and Long found that the spread seems to be enhanced by viscosity of the medicine and they regard the base of great importance. The gelatin base dyes did not penetrate the pharyngeal area and

so they concluded that the posterior wall of the pharynx cannot be reached with drugs in effective concentration from the mouth.

Silber[19] reports the interesting treatment of 21 patients with tonsillitis, pharyngitis, varying degrees of adenitis and gingivostomatitis by means of analbis suppositories containing 0.0225 gm. and 0.045 gm. metallic bismuth each, in the form of heptadienecarboxylic acid salt of bismuth.

Twenty alternate patients were used as controls. There was no evidence of toxic bismuth effects, local or systemic, irrespective of the number of suppositories used.

Silber reports that treatment with analbis was more effective than symptomatic treatment. In support of this, a report is made that recovery was effected in cases of tonsillitis and pharyngitis in 2.68 days in 14 patients treated with analbis as against 6.3 days in 15 patients treated symptomatically, and 5.3 days in three patients treated with sulfonamides.

The difficulties in determining the etiologic agent of an acute inflammation of the throat by clinical observations are well recognized. Many infecting agents produce an identical clinical picture so that a specific etiologic diagnosis can be made only by accurate laboratory methods. Tumulty and Michael[20] fully appreciated these difficulties in treating a short-lived epidemic of diphtheria which occurred on a base on a South Pacific island. Immediate microscopic examination of cultures and scrapings from throats with potential diphtheria proved valuable. If the culture revealed only a yeast-like organism and no pathogenic bacteria, a fresh preparation was made and examined; 18 cases of Monilia Albicans were found. Such infections commonly occur in undernourished and chronically ill patients; however, these 18 patients represented well nourished young men in good physical condition. There is a close clinical similarity of the pharyngitis caused by Monilia Albicans to that caused by beta hemolytic streptococcus and by C-diphtheria. The 18 cases are classified and reported in detail. Sodium perborate was successfully used in Monilia infections as a gargle.

Harrison[21] points out that the close proximity of the cervical spine to the upper respiratory tract, particularly the pharynx, exposes the vertebrae to invasion therefrom by a variety of disease processes chiefly of infective origin, such as tonsillitis, pharyngitis, abscesses, pneumonia and typhoid. Conversely, we are led to expect that primary disease of the cervical spine would manifest itself in the pharynx by inflammatory reactions.

It is interesting to note that two cases of osteomyelitis of the cervical vertebrae were described recently following tonsillectomy with a normal postoperative period of several days before the onset of secondary symptoms. Surprise is expressed at the relatively few complications following adenoidectomies in which the vertebrae are damaged at operation; however, the most frequent sign in the pharynx of vertebral inflammation is retropharyngeal abscess and a number of such cases are reported.

Kuyrkendall[22] reports a case of a girl whose uvula completely filled the pharynx and extended downward but had not affected respiration, speech or swallowing. Amputation of the uvula resulted in no subsequent change in the tone or volume of her voice. Microscopic examination revealed no signs of malignancy, although there was some tendency to irregularity in the cells of the surface epithelium.

The author states that elongation and hypertrophy of the uvula without acute inflammation may be due to chronic pharyngitis caused by postnasal discharge, or to prolonged use of alcohol or tobacco. Recommended treatment is removal of the tip or amputation. The author points out that it is important that following removal of the tip, the cut surface should face the posterior pharyngeal wall in order to avoid irritation, hemorrhage and delayed healing due to ingested food.

The edematous uvula resulting from pharyngeal operations, too much alcohol, persistent clearing of the throat or too highly seasoned food is an acute condition and will respond to treatments with astringents and elimination of irritants.

Morris[23] presents a review of histopathology, criteria for therapy and irradiation technique in cases of aero-otitis. Roentgen radiation was used in 11 cases. Treatment was given through a lateral port on each side with a 10 cm. circle centering over the Eustachian tube, the average dose being 100 Roentgens each side per treatment; it was given at seven-day intervals. Total number of treatments varied from four to six, depending upon the severity of tubal obstruction. In some cases a second series of treatments after six to eight weeks was given. No cases were treated in which psychoneurosis, allergy, chronic ear disease or chronic infection of the nose or pharynx could be demonstrated. Those patients treated in the manner outlined were all able to return to full flight duty in from four to eight weeks.

A discussion of the diagnosis and treatment of childhood conductive deafness due to nasopharyngeal lymphoid hyperplasia is presented.[24] The problems of a decision between operation and radiation for this condition are aired. In most cases the deciding factor would seem to be the amount and location of the lymphoid tissue. If a large amount of tissue is present and is more or less centrally located in the nasopharynx, surgical treatment is best, but in some cases it should be followed by radiation. If, on the other hand, the lymphoid tissue is laterally placed in or about the tubal orifices, or in the fossa of Rosenmüller, it is felt that radiation offers better results.

Radiation therapy, amounting to 400 R measures in air, is directed to the nasopharynx as the initial dose, followed a week later by a similar amount to the same area. A few of the patients complained of fullness in the parotid region and showed some swelling there following radiation. Neuhauser and Ferguson prefer Roentgen radiation to radium or radon because of its simplicity and efficiency in children.

Emphasis is placed on careful audiometric studies before and after treatment. Two audiograms, showing good response to treatment, are included as figures. Of the 16 patients having satisfactory follow-ups, 14 improved following treatment, and of these, 12 showed return to normal hearing.

Fisher[25] has been a champion of irradiation therapy to the nasopharynx and in the past five years has irradiated over 1,000 cases, with 11 per cent failures, probably because of inadequate irradiation. He states that infection of the nasopharyngeal lymphoid tissue is responsible for pyogenic infections occurring in the upper air passages. These infections by extension may produce otitis media, mastoiditis, deafness, chronic bronchitis and bronchial asthma. It has been proved by Heinlke and Akaiwa and Takeshima that lymphoid tissue is exceedingly sensitive to irradiation, and considerable reduction in size can be obtained by the proper application of this method of therapy. Repeated infections of the upper respirator tract result in hyperplasia of the lymphoid tissue, producing excessive secretion of mucus with obstruction to breathing and to the Eustachian tubes. This latter condition is frequently the cause of conduction deafness. The use of irradiation will frequently and effectively control this excessive lymphoid tissue. The radiation does not destroy or permanently remove lymphoid tissue; it merely slows up the reproduction of lymphocytes and in this way causes a gradual decrease in size. Radium applications may have to be repeated at intervals in children until the child reaches the age of puberty. After this time there is spontaneous regression of lymphoid tissue in the upper air passages in most children. Fisher thinks that if excessive lymphoid tissue in the nasopharynx is not treated by irradiation during childhood, it persists in the adult. Because of its simplicity of application and the excellent results obtained, radiation of the nasopharynx should be used more universally.

In the past few years the monel metal radium applicator for nasopharyngeal therapy, as designed and advocated by Burnam and Crowe,[26] has become increasingly popular. In a discussion of this subject it is stated that practically all spontaneous radioactive substances belong either to the uranium or thorium group of elements. Radium, by far the best known and most used of these elements, is a member of the uranium family. Since the development of the atomic bomb, the public has been made conscious of the radioactivity of uranium.

Radium is applied to the nasopharynx to reduce hypertrophied lymphoid follicles which may effectively obstruct the Eustachian orifice and to destroy infection in adjacent lymphoid tissue. To accomplish this, the authors designed a monel metal applicator, the chamber of which contains 50 mg. of radium sulfate. It has been determined that 75 per cent of the beta rays emitted by this applicator are absorbed in the first 3 mm. of tissue, and that 6 to 7 per cent of the hard beta rays are still present after passing through 20 mm. of tissue. In contrast, less than 10 per cent of the gamma rays are absorbed. Final results are entirely dependent on the amount of ray absorption and the therapeutic effect of a single dose of radiation therapy may be modified greatly by the reparative powers of the tissue.

The dosage advocated is 1 gm. 25.5 seconds on each side of the nasopharynx. Since this applicator contains only 50 mg. or 1/20 of a gram, the dosage is computed as being eight and a half minutes on each side. Because the reparative period of nasopharyngeal lymphoid tissue after such irradiation is from three to four weeks, an interval of 25 days is advocated between applications. It is thought that three applications suffice for the average case; however, circumstances may alter conditions, requiring additional applications. The presence of large adenoids may require surgical removal, followed immediately by radiation. A warning is issued against the use of radium in acute or subacute conditions of the nasopharynx. The technique of application and precautions to be taken are discussed.

Swanberg,[27] in discussing the use of radium in the nasopharynx, believes that in addition to therapy of the lymphoid tissue, irradiation is useful in the treatment of repeated colds with ear or sinus complications, aero-otitis and aero-sinusitis. He gives an excellent description of the applicator devised by Crowe and discusses its cost.

### LYMPHOID TISSUE.

The medical profession is in agreement that an adequately performed tonsillectomy permanently improves the health of

some children; in others, the improvement is only temporary, and still others show no improvement following operation. Leathart[28] questions whether it is possible, by correlating what is known of the physiology of the tonsil with physical signs and symptoms usually considered as justifying its removal, to avoid unnecessary operations and select for this treatment only those cases in which permanent improvement is predictable. His study of the physiology of the tonsil shows that all tonsils except those of a newborn child contain living micro-organisms which have gained access from food or air. Some of these continue to live; others die, and their death is caused by the immune bodies which the child already possesses; he is not yet immune to those that live. Leathart further describes how the living micro-organisms produce their toxins which are absorbed into the lymphoid system, where, by means of a biochemical reaction, antitoxins and antibodies are formed. Some of these are sent back to the tonsil by its blood supply and here they destroy the living micro-organisms; the rest remain in the blood stream. In this way the infection is controlled and immunity to it is increased. It may, therefore, be assumed that by acquiring and recovering from infections, the child acquires resistance and in time immunity to the infections in his community. Leathart says the tonsil is an organ whose function is to pick up organisms from food or air and to grow those to which immunity is needed; it is the factory in which toxin is produced and from which it is absorbed as necessity demands. It is thought that repeated infections are necessary to produce this required immunity and that the early removal of tonsils and adenoids prevents a young child from receiving adequate immunization. Several clinical conditions are enumerated in which it is thought that a tonsillectomy is advisable. The younger the child, the more important is the physiologic function of the tonsil, for upon it the future resistance to infection depends.

Fabricant[29] presents a review of a number of articles which have been published recently on the subject of tonsils and adenoids. His discussion is divided into three groups: the medicosurgical aspects; the relation of tonsillectomy to polio-

myelitis; and the application of irradiation to hypertrophied lymphoid tissue in the nasopharynx as a means of treating certain types of impairment of hearing.

In most of the articles reviewed it was the consensus that the tonsils and adenoids should be removed *only* when they are likely to have a more unfavorable influence on the patient than the dangers, disability, discomfort and inconvenience of removal would have. From numerous studies made, it is generally believed that the nasopharyngeal mucosa of the tonsillectomized patient "may be the focus of at least one added circumstance which determines the outcome of exposure to the virus, and is important not only as indicative of the *modus operandi* of autarcesis, but as providing a means of prevention." Fabricant advises, "Since this operation is practically always elective as to time, changing the season when it is done, so as not to coincide with the season of poliomyelitis prevalence, would eliminate numbers of cases of the highly fatal bulbar form of the disease." Radiation has been found successful in reducing obstructing nodules of lymphoid tissue which interfere with normal function of the tubes and cause deafness. It is more often beneficial in children than in adults.

## HEMORRHAGE.

Windham[30] frankly admits that after reading many articles on various types of rhinopharyngeal hemorrhage, he knows no more about the subject than before, because most of the articles are concerned with blood dyscrasias. He believes that coagulants, sera and vitamins are of no value in treating hemorrhages. Nasal hemorrhages are classified as spontaneous and traumatic. Spontaneous hemorrhages in patients under 40 years of age are usually from the anterior end of the septum, whereas in patients over 40, the greater number is due to rupture of vessels at the posterior end of the septum, the posterolateral nasal wall or the middle turbinate. Traumatic hemorrhages are usually self-evident.

If the bleeding point can be seen, it is best treated by cauterization with the actual cautery or the diathermy needle.

Trichloracetic acid may also be used. In cases of traumatic hemorrhage, packing is the method of choice.

The blood supply of the area is an important consideration in postnasal hemorrhages. The postnasal area is supplied by the terminal branch of the internal maxillary artery and by the anterior and the posterior ethmoidal arteries, which are branches of the internal carotid. If the point of hemorrhage can be discovered, it should be cauterized. If the bleeding point cannot be discovered, the anterior ethmoidal artery should be ligated because it is the offending vessel in 95 per cent of the cases. If it can be determined that bleeding comes from the sphenoidal artery, transantral ligation of that vessel or of the external carotid can be performed, but if bleeding is from the posterior ethmoidal, the only recourse is ligation of the internal carotid.

In general, packing is not advocated. It is unsure and exhausting to both the patient and the physician. Spontaneous hemorrhage from the throat is rare, but after operations on the tonsil bleeding may occur.

No mention is made of hemorrhage due to nasal and postnasal neoplasms, or infections, or of the hemostatic, as well as supportive value of transfusion in bleeding in these areas from any cause.

Woodruff[31] reports the case of a 17-year-old boy who, following the spontaneous rupture of a peritonsillar abscess, suffered three massive hemorrhages from the pharynx. It was decided to ligate the large vessels of the neck. Ligation of the external carotid did not control the bleeding, but hemostasis was secured after the common carotid was tied off. Convalescence was uneventful.

In hemorrhage due to peritonsillar abscess, the responsible vessel is usually the external carotid, but when the analysis includes suppuration in all the connective tissue spaces about the pharynx, the lesion in the majority of cases is found to be in the internal carotid.

It is supposed that in a suppurative process in the neck,

one of the large vessels may be seriously eroded, but hemorrhage does not occur because of the pressure of the confined pus and the surrounding inflammatory zone. When, however, the abscess is incised or ruptures spontaneously, the release of the pressure is followed by hemorrhage.

Woodruff feels that the procedure of choice in the great majority of massive pharyngeal hemorrhages is still ligation of the common carotid. Rarely, it may be necessary subsequently to ligate either the internal or the external carotid in order to shut off active collaterals.

Recurrent hemorrhage from the nose and nasopharynx may at times become extremely serious and even cause death. Such cases are reported by Sargent[32] in an interesting article in which he discusses massive recurrent hemorrhage from erosion of a blood vessel beneath the surface where the source of the bleeding is not immediately evident. Such bleeding is usually arterial rather than venous. Nature attempts to forestall hemorrhage by thrombus formation, and this attempt is most likely to fail if the vessel is a sizable artery. One would expect the incidence of cerebral embolism to increase in such cases. Hemorrhages originating in the pharyngomaxillary fossa have received more attention than those from other regions. Salinger and Pearlman concluded from a study of 231 cases of all types of hemorrhage in this region that ligature of the common carotid is the treatment of choice, and autopsy of fatal cases showed the internal carotid eroded more frequently than the external carotid, superior laryngeal and ascending pharyngeal arteries. Recurrent massive hemorrhage in which the artery is not ligated has a mortality rate of 60 to 80 per cent.

Hochfilzer[33] reports the case of a two-year-old girl who had a retropharyngeal abscess with massive hemorrhage which was successfully treated by ligation of the left common carotid. Hemorrhage from the retropharyngeal region is serious and may cause immediate death, or, as in the case reported, there may be several hemorrhages at intervals and proper treatment must be administered at once. Ligation of the com-

mon internal or external carotid artery is necessary to save the patient's life. Minor hemorrhages can be controlled by local measures.

## POLIOMYELITIS.

Hilbish[34] describes a case of bulbar poliomyelitis with pharyngeal paralysis in which usual feeding methods by transnasoesophagogastric tube, by the intravenous, subcutaneous and rectal routes, were unsatisfactory after repeated trial. Gastrostomy was performed under local anesthesia and the patient fed adequately for 23 days by this method. It is claimed that a search of the literature revealed no other similar case. Following return of function of the pharyngeal muscles, the gastrostomy tube was removed and the wound healed uneventfully.

This article[35] is an extension of the observations in a previous report on the recovery of poliomyelitis virus from the oropharynx in 50 per cent of a group of 14 patients with poliomyelitis during 1943. Poliomyelitis virus was found to be present in 43 per cent of a series of 23 patients with the spinal and bulbar paralytic and non-paralytic forms of poliomyelitis from whom swabs were taken during the first three days of illness. Howe and associates state that since they employed only one test animal for each sample and were able to demonstrate virus in 43 per cent of the acute cases, it seems probable that virus is "in reality present much more frequently than the test indicates." In none of the 13 cases was virus found after the third day of illness.

## DIVERTICULA.

In discussing diverticulum of the pharyngoesophageal junction, Harrington[36] states that the condition was first observed by Ludlow, in 1767. A diverticulum may occur in any part of the pharynx or esophagus; when present they are classified as either pulsion or traction diverticula. Pharyngoesophageal diverticula are of the pulsion type and are essentially herniations of the mucous membrane through the wall of the esophagus.

Whether pulsion diverticula originate in one or more areas has been a subject of considerable discussion. Maes and McFetridge believe that they always occur at the same point in the posterior wall of the pharynx directly back of the cricoid at the junction of the pharynx and esophagus. Lahey states they occur at a region in the lowest fibres of the inferior contrictor muscle and when a defect exists in the posterior wall where the cricopharyngeus muscles diverge from the lowest fibres of the inferior constrictor. Shallow thought the most common site of origin was the area above the cricopharyngeus muscle, occurring more frequently on the left.

Harrington reports the study of six cases observed at necropsy in patients dying of other causes. The opening in three instances was through a defect in the left posterolateral wall of the pharynx between the inferior constrictor and the cricopharyngeus muscles. A similar opening was found in one case on the right side, and in the remaining two, the opening was posterior through the lower fibres of the cricopharyngeus muscle above the esophagus. The uniform relationship of the cricopharyngeus muscle to the site of the herniation suggests the possibility of weakening of this area from congenital malformation. The cricopharyngeus is the chief closing muscle of the esophageal opening. If some malformation of this muscle exists, it may perform its functions satisfactorily during early life; however, the elastic tissue attachments weaken with abnormal stress and atrophy of increasing years, and a herniation may develop as a result of constant and increasing pressure on this congenitally weak region.

Harrington reports 140 cases, of which 107 were males and 33 females. The earliest symptom was dysphagia. Complete extirpation of the diverticulum by operative measures is generally accepted as the only method that will completely relieve the symptoms. There still exists a difference of opinion as to whether diverticulectomy should be performed in one or two stages. In the last 107 operations performed by Harrington, the one-stage procedure was satisfactorily employed; this technique is described.

## TUMORS.

The usual symptoms presented by tumors of the nasopharynx, according to Yount,[37] are: *1.* obstructed nasal breathing, *2.* obstruction of the Eustachian tube with tinnitus, impaired hearing, and even mastoiditis, and *3.* mild epistaxis. It would seem that the majority of these complaints could be classified as late symptoms; however, because there is no early pain in these cases, the symptoms, plus the presence of enlarged glands posterior to the ramus of the jaw, should make one conscious of the possibility of a tumor of the nasopharynx. Tumors of the nasopharynx are rare, especially in children, and for this reason Yount reports an angioendothelioma occurring in a child four years of age. A partial review of the literature reveals that in 1941, Stout, in reviewing 70,000 patients in the Bordeaux otorhinologic clinic found only 32 tumors of the nasopharynx. Ninety-five per cent of these were in men. In a review of 82 tumors of the nasopharynx at the New York Presbyterian Hospital, 72 per cent were found to be malignant, and it was observed that the incidence of malignancy of the nasopharynx was especially high in Chinese. Endotheliomas grow rapidly and bleed easily. These tumors do not metastasize frequently but invade all surrounding tissue, causing early bone necrosis and involvement of the cranial nerves. A happy characteristic of endotheliomas is their extreme sensitivity to radium and Roentgen ray. In spite of the fact that the nasopharynx is an extremely difficult spot to reach, radiation offers the best therapy as surgical treatment and the cautery are both unsatisfactory.

Bey[38] reports six cases of mixed salivary tumors of the palate. The patients first complained of discomfort while chewing food, and later, ulceration produced pain which was followed by "pressure symptoms." All the growths were unilateral. Operation is not difficult because of encapsulation and there is little bleeding. There was one tumor which was malignant; diathermy was used for removal and the wound left unsutured in order to favor closure by granulation. In

the rest of the cases the wound was partially closed and a small gap left for drainage.

Woodman[29] states that the most usual malignant growth found in the nasopharynx is an epithelioma and it generally begins on the lateral wall well above and around the Eustachian cushion. Symptoms are few in the early stages. Swelling, hemorrhagic discharge and deafness from obstruction of the Eustachian orifice are fairly well advanced signs of trouble, and metastatic glands at the angle of the jaw represent late extension. The growth is usually radiosensitive and, although Woodman advocates the use of radium plaques, he discusses the difficulty of their proper application. No mention is made of deep Roentgen-ray therapy, which is the treatment of choice in this country and from which such excellent results are obtained.

Sarcomas of the nasopharynx also occur and may give rise to severe hemorrhage. Radiation is recommended as the best treatment, but in spite of this, the prognosis is very bad.

Malignant disease of the oropharynx is practically always squamous epithelioma and is very radiosensitive. The growth is usually found on the lateral or posterior walls of the pharynx, and Woodman is in accord with his American colleagues in saying that surgical treatment offers very little in this type of case. Malignant disease of the hypopharynx gives little or no early warning of its presence. Often an enlarged cervical gland represents the first sign of impending trouble. Dysphagia is usually a late symptom and its presence generally indicates a fairly extensive lesion. Woodman reminds us that because of the vascularity of this area, rapid extension of the lesion frequently occurs. These growths do not respond satisfactorily to Roentgen therapy and surgical intervention is fraught with much difficulty. The lower the growth the worse the outlook, and carcinoma of the sphincter at the entrance of the esophagus is incurable by any means available.

Malignant disease of the tonsil frequently extends into and invades the pharynx; therefore, it is important to discuss this

type of malignancy. By far the most common growth invading the tonsil is an epithelioma, but sarcomas not infrequently occur and mixed tumors of the parotid are not rare. The latter forms an encapsulated, slowly growing, painless tumor which may give rise to difficulty in speech and deglutition. Surgical enucleation is the best treatment for mixed tumors. Woodman thinks that sarcoma of the tonsil is as serious as sarcoma in a long bone and as deadly. It disappears quickly by the action of radium needles or Roentgen therapy, only to reappear in the cervical glands, lungs and mediastinal spaces.

Epithelioma of the tonsil is a relatively common form of cancer. Originating in the substances of the tonsil, it spreads rapidly to the surrounding tissue and it has been proved by experience that extension into the sulcus between the tonsil and the tongue is extremely dangerous. Woodman advocates the accurate insertion of radium needles and block dissection of the cervical glands. The prognosis of carcinoma of the tonsil is good and, according to Woodman, represents one of the triumphs of modern radium therapy.

Some of Woodman's views are most interesting. He states that in malignancies the history of alcohol, syphilis and tobacco is important. "Tobacco in excess renders anesthesia difficult and subsequent pneumonia probable. Syphilis aggravates the rate of growth but is not fatal; treatment of the growth is undertaken and at the same time that of the venereal disease. Of the three, alcohol is the most lethal; malignant cells roaming about in tissues soaked in alcohol find themselves in paradise. There is little hope of a cure by operation, radium or X-rays in an habitual alcoholic."

Lawrence and Brezina[40] report their findings in a consecutive series of 145 cases of carcinoma of the oral cavity seen at the New Haven Hospital from Jan. 1, 1931, to Dec. 31, 1940, inclusive. Their study was designed to give the results of treatment, to discuss the causes of failure and the reasons for good results, and to suggest ways whereby the results might be improved. The series includes only those patients who received their initial treatment at the New Haven Hospital. The largest number of cases was in the hypopharynx

and posterior tongue. The best survival rate was obtained in the groups of the anterior tongue and buccal mucosa, and the worst results in the hypopharynx. Involvement of the lymph nodes always makes the prognosis more serious and in this series 65 per cent of the total of 108 cases had lymph node involvement on admission, or developed it at a later date, and only 5.6 per cent of these survived five years. Of 37 patients who had never had lymph node involvement, 35 per cent were living at the end of five years. Radiation is the treatment of choice for carcinoma of the mouth and pharynx. Only three of the cases in the five-year survival group were treated surgically; all the rest received radiation.

The authors attribute failures to the frequency of lymph node involvement, inability to control the primary lesion, delay in seeking treatment and chronic infection in the mouth. They emphasize the importance of educating the public as well as young physicians and dentists in recognizing the signs and symptoms of the eary stages of the disease.

Stevenson and Eckhardt[41] report an unusual reaction to intensive Roentgen therapy to the neck and the oropharynx for lymphoepithelioma in a 43-year-old man. About two years after the Roentgen therapy, signs of transverse myelitis appeared in the region of the fourth cervical segment and rapidly led to death from respiratory paralysis. Additional radiation did not check the progress of the disease. Exploration of the cervical part of the spinal cord revealed no evidence of epidural or intramedullary growth and no apparent vascular changes. Postmortem examination showed myelomalacia of the cervical part of the spinal cord in the vicinity of which there were many thickened arterioles with fibrous walls.

Because small lesions in the nasopharynx, which are apt to be serious, are frequently overlooked, Prohovnik[42] reports a case of carcinoma of the nasopharynx in a 14-year-old boy whose sole complaint was epistaxis. He gave a history of repeated attacks of epistaxis and painful cervical enlargement of four months' duration. Examination with the pharyngoscope disclosed a sessile, firm, irregularly roundish mass

about 3 cm. in diameter, in the left side of the nasopharynx. Biopsy revealed the growth to be transitional cell carcinoma. Eight months following intensive radiation therapy, there was no evidence of the tumor and the glands in the neck had completely disappeared; however, Prohovnik did not consider this patient cured because these tumors metastasize rapidly and the ultimate course in this case cannot be predicted.

Over a five-year period, 16 cases of transitional epithelial cell carcinoma, also known as "lymphoepithelioma" and "anaplastic epidermoid carcinoma," occurring in the nasopharynx were observed and treated by Whiteleather.[43] A discussion of the history and microscopic pathology of this lesion is included. The lesion is most commonly primary in the fossa of Rosenmüller or the pharyngeal tonsil. All ages and sexes may be affected. The disease is very malignant in children and young adults. One of the earliest symptoms is Eustachian tube obstruction, which may be followed later by nasopharyngeal obstruction, cranial extension and cervical and more distant metastases. It is felt that radiation therapy offers the most hope at present for cure or palliation, depending on the extent of the lesion. A better result is expected in cases in which cranial extension or metastasis has not occurred. Three of the 16 cases were free of disease after two and one-half years.

Gollom[44] states that a great deal of confusion seems to exist as to the nomenclature and biologic nature of malignant tumors of the upper respiratory tract. Most authorities include lymphoepitheliomas among the nonkeratinizing group of epithelial tumors, whereas others regard them as a form of reticulum cell sarcoma. The microscopic appearance of the tumor varies considerably and, although there is a great difference in size and shape of cells, numerous mitotic figures are usually present and the tumor is considered highly malignant. The chief primary sites are the orifice or the Eustachian tube, the posterior nares, the vault of the pharynx and the tonsillar areas; it has been noted that lymphoepitheliomas grow slowly at their primary site but metastasize early. New reports that enlarged cervical glands on one or both sides of

the neck represented the first symptoms in 42 per cent of 194 cases with nasopharyngeal tumors. Sooner or later it occurs in the majority of cases. The other symptoms manifested as the tumor progresses are those of obstruction and epistaxis.

Gollom emphasizes the point that lymphoepitheliomas and related malignancies of the nasopharynx do not respond satisfactorily to surgical treatment. Radiation is the treatment of choice in all cases, and five-year cures are reported in about 25 per cent of the cases. Gollom reports the treatment of these tumors as advocated by Charles Martin, who, in addition to irradiating the primary area, directs treatment to areas where metastases are likely to occur, even though no metastases are detected at the initial visit. It is a well known fact that nasopharyngeal tumors occur more frequently in the Chinese, and to substantiate this fact further, Gollom reports a case of lymphoepithelioma in a 38-year-old Chinese man treated successfully with fractional doses of deep Roentgen therapy.

## TUBERCULOSIS.

Because there are many unsolved problems pertaining to the pathology and pathogenesis of tuberculosis of the nasopharynx, Hollender and Szanto[45] undertook a study of its incidence, pathology and clinical significance. It was their opinion that tuberculosis of the nasopharynx occurs in the course of pulmonary tuberculosis, probably more frequently than tuberculosis of the larynx, and this was confirmed by their study of 24 subjects with varying forms of pulmonary tuberculosis; they found that the nasopharynx was involved in 18 specimens (75 per cent). In four of these 18 specimens, tuberculosis could be demonstrated only by careful microscopic examination.

Hollender and Szanto theorize, on the basis of their observations, that nasopharyngeal tuberculosis may be primary, which is exceptionally rare, or secondary, which is the one commonly observed.

The gross pathologic changes are usually characterized by

irregular ulcers, commonly ovoid, with undermined margins and yellowish-gray bases. Histopathologic changes are seen as subepithelial tubercles, composed of epithelioid cells, giant cells, incipient or advanced caseation necrosis and are found primarily in the remnants of the lymphatic tissue.

Hollender and Szanto distinguish between two types of tuberculosis of the nasopharynx: the open or tuberculous ulcers and the closed type. They state that it is reasonable to assume that the nasopharynx may be the persistent source of reinfection of the lungs. They believe that in all cases of pulmonary tuberculosis routine examination shall include thorough investigation of the nasopharyngeal cavity.

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## COURSE IN OTOLARYNGOLOGY, RHINOLOGY AND LARYNGOLOGY.

The Eleventh Annual Graduate Convention in Otology, Rhinology and Laryngology will be held at the University of Cincinnati College of Medicine, April 14 to April 19, inclusive, 1947. This is to be an operative course on the cadaver and didactic lectures.

# PHYSICAL CHARACTERISTICS OF HEARING AIDS.*

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The present-day wearable hearing aid consists essentially of three parts, the microphone, which generates an electrical voltage when a sound actuates its diaphragm, the amplifier, which amplifies that voltage many-fold, and the earphone, which converts the amplified voltage into sound which is brought into the wearer's ear through a fitted earpiece. Since the hearing aid is a miniature communication system, similar to the telephone or interphone, the electrical and acoustical characteristics which determine its performance are those which are generally important in all communication systems.

The laboratory test methods by which the performance characteristics of a hearing aid are measured are designed to simulate, to a reasonable degree, the conditions under which a hearing aid is actually used. The arrangement of equipment is shown in Fig. 1. A pure tone of known intensity is supplied by a loudspeaker (sometimes called an "artificial voice") to the hearing aid, which is mounted on a stand at some distance in front of the loudspeaker. The earphone of the hearing aid is placed on an "artificial ear" (2 cc. coupler). The artificial ear is a device with a cavity in it which simulates the cavity formed by a human ear with a molded earpiece inserted. A small microphone in the artificial ear is used for measuring the sound developed by the earphone. Details of the artificial ear may be seen in Fig. 2. The small tubular channel represents that of the earpiece, and the 2 cc. volume represents that volume adjacent to the eardrum when a molded earpiece is in the ear.

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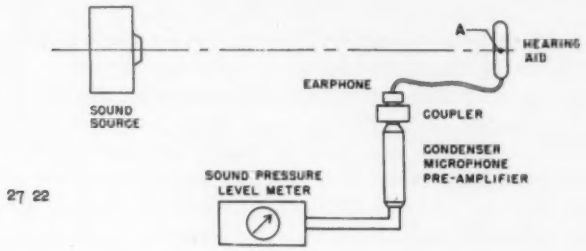
## AMPLIFICATION CHARACTERISTICS.

For a hearing aid, the prime requisite is obviously amplification of sound. The sounds transmitted to the wearer's ear by the instrument must be considerably louder than they are




KNOWN FREE-FIELD SOUND PRESSURE LEVEL $p_1$ AT POINT A.
SOUND PRESSURE LEVEL $p_2$ DEVELOPED BY RECEIVER IN COUPLER.
$p_2 - p_1$ = OVERALL ACOUSTIC GAIN OF HEARING AID.

Fig. 1.

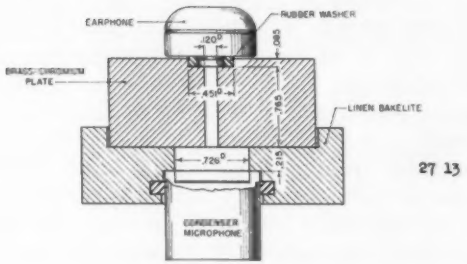



Fig. 2.

normally presented to the unaided ear, if they are to be heard and recognized. The amplification, as measured in the laboratory, is simply the difference between the sound level at the microphone of the aid and the sound level produced in the artificial ear by the earphone, expressed in decibels. Since most instruments provide what is called "selective amplification," *i.e.*, amplify tones of some frequencies more than others, it is necessary to state the frequency of the sound for which

the amplification is measured. In order to describe the amplification characteristics of a hearing aid, the data are plotted as a graph of amplification against frequency, as shown in Fig. 3.

Such a graph is customarily referred to as a "frequency-response" curve, or simply a "response" curve, since it indicates the response of the instrument to an applied sound of a

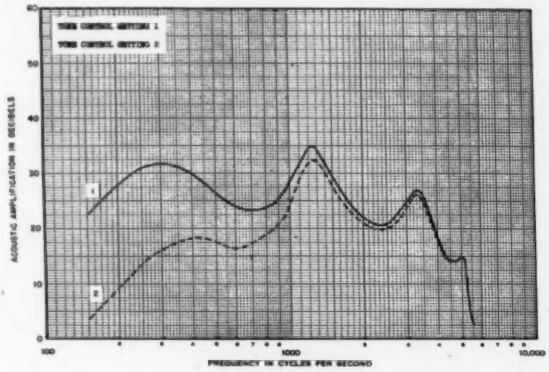


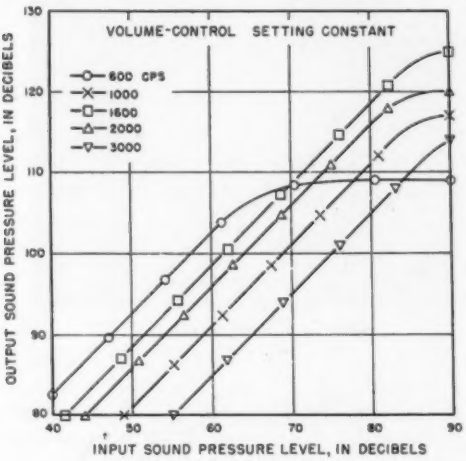

Fig. 3.

given level, at various frequencies. An instrument whose amplification is the same for sounds of all frequencies is said to have a "flat" response characteristic, since its response is represented by a straight horizontal line on the graph.

The effect of the tone control on a hearing aid is to alter the relative shape of the response curve, in much the same manner as the tone control on a radio set. For instance, a change of tone control setting might change the response from that indicated by the solid line to that of the broken line. Tone control setting "2" gives less emphasis to low frequency sounds than to those of high frequencies, as compared with setting "1." A third tone control setting might also be provided to reduce the response at high frequencies relative to that at low frequencies.

## MAXIMUM ACOUSTIC OUTPUT.

Response data, such as those shown in Fig. 3, are taken with the volume control set at some given position. For most hearing aids, a change in the volume control setting merely increases or decreases the amount of amplification fairly uniformly at all frequencies, without altering the relative shape of the response curve, provided that the level of the input sound at the microphone is not too high.




27 2

Fig. 4.

With a given setting of the volume control, however, as the level of the sound applied to the microphone is increased the level of the sound coming from the earphone reaches a maximum beyond which it cannot go, as shown in Fig. 4. There is a kind of ceiling imposed upon the amount of sound that can be produced in the ear of the wearer, which is usually different for sounds of different frequencies. The high points on the curves indicate the maximum sound levels that can be produced in the ear, regardless of how loud a sound is applied to the microphone.

These maximum points are important to the wearer of a hearing aid, since sudden unexpected loud sounds, such as the slamming of a nearby door, may produce amplified sound levels in his ear which are extremely unpleasant, or even painful, unless the hearing aid limits them to values which are below his threshold of feeling. If the maximum points of these curves are plotted against the corresponding frequencies, a graph of maximum acoustic output is obtained, as shown in Fig. 5. For the sake of comfort and safety, this

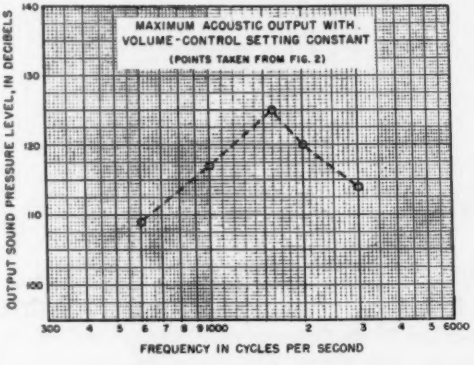


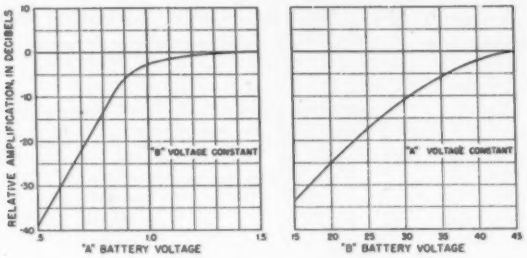

Fig. 5.

curve should lie below the upper tolerance limit of the wearer's ear for loud sounds.

## AMPLIFICATION VS. BATTERY VOLTAGE.

The amplification of a hearing aid depends upon the voltage of the A and B batteries used with it. It is of value in the "fitting" of a hearing aid to know the amplification of the instrument for various battery voltages. This information is also of pointed interest to the wearer of a hearing aid, who wishes to obtain the required amplification from it for as long a time as possible before having to replace rundown batteries. Typical data are shown in Fig. 6. The manner in which amplification changes with varying battery voltage

depends upon both the design of the hearing aid and the type of battery used. To supplement this information, the amount of current drawn from the batteries is measured with a milliammeter. The greater the current drawn by the aid, the shorter will be the useful life of the batteries, in general.



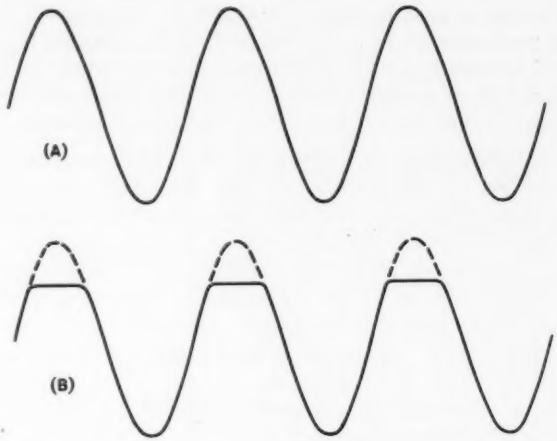

27 8

Fig. 6.

## DISTORTION.

When the sounds produced in the ear by a hearing aid are not identical, except for amplification, with those which are presented to its microphone, "distortion" of the sounds is said to occur. The term "distortion" is usually applied to the case in which the wave-form of a sound is altered in character by the hearing aid. Sound consists of alternate compressions and rarefactions of the air, so that the air pressure at a point in the sound field alternately increases and decreases many times per second. For example, the sound pressure at the microphone of a hearing aid due to a pure tone may be shown as in the upper graph of Fig. 7, where time is represented on the horizontal axis. Distortion occurs when the hearing aid does not exactly reproduce this sound wave-form in the ear. An example of one type of distortion is shown by the full line of the lower graph of this figure, in which the peaks of the sound pressure (broken lines) are "clipped." Analysis shows that amplitude distortion results in the production of extraneous tones (harmonics) in the sound from the earphone in addition to the original tone applied to the instrument. The

percentage of the total sound which resides in these extraneous tones may be taken as a measure of the distortion. If a




27 4

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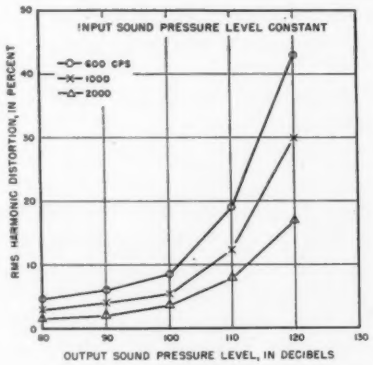
Fig. 7.



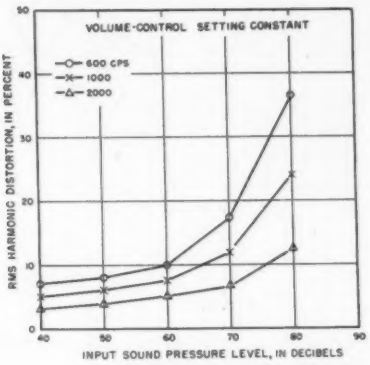

27 7

Fig. 8.

constant sound is applied to the hearing aid, distortion usually increases as the volume control is turned up, as shown in Fig. 8. Similarly, distortion usually increases if the volume

control is set at one position and the sound applied to the hearing aid is increased in level, as shown in Fig. 9.

Unfortunately, the percentage distortion as measured by the usual methods is a somewhat ambiguous criterion of the quality of performance of a hearing aid. For example, large amounts of certain types of distortion do not seriously affect the intelligibility of speech, whereas relatively small amounts




27 6

Fig. 9.

of other types of distortion may render speech almost completely unintelligible.

## NOISE.

Noises arising in a hearing aid may be classified into two general types, according to their causes: electrical and microphonic noises. The most common electrical noise is the hissing sound due to passage of electric current through the circuit elements of the aid. Another type of electrical noise that is sometimes encountered is a humming or buzzing sound that occurs when the instrument is worn near electrical machinery or equipment. Such noise may usually be minimized by proper electrical shielding in the instrument.

Microphonic noises occur when the hearing aid is jarred or rubbed; friction against the wearer's clothing is a frequent

source of microphonic noise. Careful choice of case material and design, elastic mounting of the microphone in the case, and use of a soft cloth covering or "carrier" for the instrument will help to reduce noises due to rubbing of clothing against the case. Elastic mounting of the vacuum tubes within the case sometimes helps to reduce bell-like ringing noises which are due to vibration of the elements within the tubes.

### HEARING AID PERFORMANCE UNDER CONDITIONS OF USE.

The standard laboratory tests of physical performance characteristics were designed to provide test conditions fairly similar to those under which a hearing aid is used and still employ relatively simple and easily duplicable equipment, so that various laboratories testing a given instrument will obtain the same results. It should be strongly emphasized that there are certain important differences between laboratory test conditions and those under which a hearing aid operates when worn by an individual. It is not always safe to apply data taken in the physical laboratory to the problem of "fitting" a hearing aid, for reasons which follow:

In the first place, the cavity of the artificial ear is only an approximate simulation of an "average" human ear. The walls are rigid, whereas in the human ear the walls are softer and more yielding, and as a result there is considerable acoustic damping in the human ear. Many earphones, when measured on the artificial ear, exhibit response characteristics which are highly peaked at some frequency or frequencies. When they are used on the human ear, these peaks may be absent or greatly diminished.

In the second place, the artificial ear is so designed that the earphone is coupled tightly to it with the aid of a rubber sealing ring. In use on the human ear, the earphone may not fit tightly to the molded earpiece, and sound may leak out through the junction. This will affect the response of the hearing aid to a greater or lesser extent, depending upon the size of the leak.

If the molded earpiece does not fit the ear snugly, sound may also leak out between the ear and the earpiece. This may

cause not only oscillation, or "feedback" howling, but may also have a pronounced effect on the response characteristic. It is important, therefore, that an individual should have his own molded earpiece before trying various hearing aids for purposes of selecting one to suit his needs.

In the third place, the amount of clothing which is worn over the hearing aid will have some effect on the response of the instrument. The effects will vary from person to person, depending particularly upon the amount and character of the clothing covering the instrument. In most cases, reasonably good compensation can be made for them by a tone control which emphasizes high frequency response.

Comprehensive studies of the effects of various conditions of use on the performance of hearing aids have been made at the Swift and Psycho-Acoustic Laboratories at Harvard. Papers covering the results of these investigations in detail are now in preparation for publication in the *Journal of the Acoustical Society of America.*

## CONCLUSION.

To summarize, the important physical characteristics of a hearing aid are: the amount of amplification, the shape of the frequency-response characteristic, the maximum sound level which can be produced in the ear, and the degree and type of distortion of a transmitted sound. It is tacitly assumed that mechanical ruggedness and freedom from noise, along with stability of performance, regardless of temperature and humidity conditions, are desirable characteristics.

Standard laboratory tests for measuring physical characteristics are in common use in many laboratories in this country. The results of such laboratory tests are very useful for purposes of design, comparison and control of characteristics in production of hearing aids; however, they should not be applied indiscriminately to problems of "fitting," or selection, of hearing aids without due consideration of the differences which may exist between laboratory test conditions and the conditions under which the instruments operate when worn.

## HEARING AID CLINICS IN ENGLAND.*

A. W. G. EWING, Ph.D. (by invitation),
Manchester, England.

During World War II, the number of hearing aid clinics in London and other cities was temporarily reduced by enemy action or by diversion of the staff to essential war needs. Before the war ended, however, His Majesty's government decided that a new survey of the problems of deafness should be made from every angle. As the result of the request from the Ministry of Health, three committees were established by the Medical Research Council. The first was the Medical and Surgical; the second, a Committee on the Educational Treatment of Deafness, including representatives of the Ministries of Education, Health and Pensions, with educationists, otologists, psychologists and representatives of the Scottish Health Department; third, an Electro-Acoustic Committee comprising a number of the leading authorities in acoustics and telephone engineering.

The function of these committees is to promote and to coordinate investigations in the ascertainment and treatment of deafness and the design and construction of hearing aids, and pure tone and speech audiometers. Financial support is given through the Medical Research Council. The experimental work is being done in London, at the National Hospital; at Manchester University in the Department of Education of the Deaf, and at the National Physical and Post Office Research Laboratories.

The needs of veterans are by no means overlooked, but the main objective is to deal with the permanent problem of defective hearing in children and civilian adults.

The new Otological Research Unit, under Dr. C. S. Hallpike, admits patients, at small fees, for otological exami-

*Read by invitation at the Seventy-eighth Annual Meeting of the American Otological Society, Inc., Chicago, Ill., May 31, 1946.

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nation, audiometry and tests with aids. The Manchester University Clinic has equipment duplicating that at Dr. Hallpike's Unit.

Our department is staffed and equipped also to investigate the educational treatment of deafness in all its aspects, including its ascertainment in infants and young children, the application of electro-acoustical equipment to problems arising from defective hearing among school children, and the rehabilitation of deafened adults by educational methods and the use of aids. No fees are charged, but voluntary contributions to the department's Research Fund are invited.

There is a small number of other hearing aid clinics attached to hospitals in London and elsewhere, but at present none of them is included in the research organization sponsored by the Medical Research Council.

The responsibility of public health authorities to treat children who are physically or mentally handicapped was considerably extended by the Education Act of 1944 and the corresponding Act in Scotland.

Many problem cases, including children with delayed speech and suspected aphasics, are referred to the Manchester University Clinic.

At the request of public health and education authorities and of the Society of Medical Officers, courses are also provided by us in audiometry and tests of hearing for medical officers, nurses and health workers at different centers in England and Scotland.

At Manchester University the procedure followed with children of school age includes pure tone audiometry and also speech tests. These are usually made with lists of words or syllables, scored on the basis of the number of consonants and vowels heard and repeated correctly by the child. It is essential to know how far a school child can follow what is said to him with enough clarity for him to acquire unfamiliar information and new terms and phrases in two sets of acoustic conditions. These correspond, first, to those of normal, quiet

conversation, *e.g.*, with parents and other boys and girls; second, to those encountered in school, which often resemble the acoustic conditions of a noisy auditorium.

The Ministry of Education has adopted as fundamental the principle that no child with defective hearing should be admitted to a special school for the deaf or hard of hearing if by educational treatment and the use of an aid he can continue to make good progress in an ordinary school. It is recognized, however, that school conditions are more exacting than those encountered in private conversation and that the school pupil needs to be able to follow speech with a high syllable articulation, where an adult who has become deaf can get along with good sentence and syllable articulation of a relatively poor standard.

In our experience successful use of aids and the practice of lipreading by hard of hearing or partially deaf pupils retained in ordinary schools depends, first, on the efficiency of the training that they have received; second, on the amount of cooperation given by teachers and fellow-pupils. In general, it is upon the qualified teacher of the deaf, trained to teach with the help of aids and familiar with the factors governing the development of speech and language that the educational, social and economic future of the partially deaf child depends.

As yet, adequate provision has not been achieved for the partially deaf and hard of hearing, as distinct from the child whose deafness is so severe or of such early onset that he comes to school mute. Yet, these two classes of children have specific needs and should not be educated together in the same school. The choice has often to be "school for the deaf" or "ordinary school," with part-time lipreading instruction and speech correction, so far as facilities are available. In the clinic, therefore, tests of vocabulary and verbal comprehension, as well as tests of educational achievement and performance tests of intelligence are made.

I can summarize only briefly the trends of British work on the rehabilitation of deafened adults. The aim is comprehensive and to combine every available means of help. Testing

approximately 100 patients with an average hearing loss of 62 db., we obtained these scores for the accuracy with which they followed sentence lists:

*a.* Unaided hearing without lipreading, 21 per cent.

*b.* Unaided hearing with lipreading, 64 per cent.

*c.* Individual vacuum tube aids without lipreading, 64 per cent.

*d.* Individual vacuum tube with lipreading, 90 per cent.

In connection with our clinic, classes in hearing aid instruction are combined with training in lipreading, especially for older patients, to whom speech is not intelligible through an aid alone.

A report has been prepared by the Electro-Acoustics Committee on the whole program of hearing aids. In it many of the problems discussed in this session are dealt with. When it has been released by the Medical Research Council, we shall look forward to hearing the views of our American and Canadian colleagues about our British methods and results.

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## AMERICAN BOARD OF OTOLARYNGOLOGY.

The American Board of Otolaryngology will conduct the following examinations in 1947:

April 16 to 19 in St. Louis, Mo., at the Coronado Hotel.

October 7 to 11 in Chicago, Ill., at the Palmer House.

Address inquiries to Dean M. Lierle, M.D., Secretary-Treasurer, Iowa City, Iowa.

# PERIESOPHAGITIS.

CHARLES C. WOLCOTT, M.D.,
Bronxville, N. Y.

This paper will consider only those cases of periesophageal infection secondary to trauma from foreign body or instrumentation. Such infections offer the endoscopist one of his most serious complications, and early accurate diagnosis and prompt adequate treatment are imperative to avoid a fatal result.

There have been many contributions to the literature on this subject. In 1889, Hare[1] wrote a book on "Pathology, Clinical History and Diagnosis of Affections of the Mediastinum." In 1895, Ziembicki[2] reported a case of posterior mediastinal abscess secondary to foreign body perforation of the esophagus. External cervical drainage was instituted but the patient succumbed three months later. In 1899, Heidenhain[3] reported a similar case following the swallowing of a chicken bone. Cervical and posterior mediastinal drainage was done and the patient recovered. While several other cases were reported in the next 15 years, it was not until 1916 when Marschik,[4] of Hajek Clinic, described the technique of cervical mediastinotomy. His technique has served as the basis for most cervical approaches since that time. In 1921, Lerche[5] advocated that dorsal mediastinotomy be added to cervical drainage, if the cervical drainage proved inadequate. It is interesting to note that in 1924, Berry[6] reported a case of retropharyngeal abscess secondary to foreign body in which drainage was established through an incision in the posterior pharynx. Death occurred the ninth day, but the author was of the opinion that external operation would have hastened the fatal outcome. In 1925, Lilienthal[7] discussed mediastinitis extensively, outlining varieties, symptoms and treatment.

In 1928, Seiffert[8] reported a case of mediastinal abscess due to esophageal perforation. The patient experienced dys-

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phagia following eating of bread. A bougie was passed. This was followed by cyanosis, dyspnea and pain between the shoulders. Esophagoscopy revealed a perforation through which blood and fluid escaped. This perforation was slit for 15 cm. The patient recovered. In 1929, Furstenberg[9] published an authentic study of the anatomy of the cervical fascia and the fascial pathways from the neck to the mediastinum. His surgical conclusions were that mediastinal suppuration below the level of the fourth dorsal vertebrae requires posterior mediastinotomy. Above this, the cervical approach is adequate; however, diagnosis of the extent of the suppuration may offer considerable difficulty. It follows that after cervical drainage the dorsal route must be employed if improvement is not prompt. Orton,[10] in 1930, reported six cases of mediastinitis following esophageal foreign body, with five deaths. He was then not certain whether conservative or immediate operative treatment should be employed.

Heatley and Pearse,[11] in 1932, stated that immediate external drainage should be done if improvement is not prompt.

Moersch and Kennedy,[12] in 1933, believed that no definite rule could be laid down as to therapy. They reported five cases, two of which were operated upon and both died.

Lederer and Fishman,[13] in 1934, suggested that prophylactic cervical mediastinotomy might be the best treatment.

In 1938, Philips[14] reported 20 cases of mediastinal abscesses. He concluded that when perforation is definitely established, surgical intervention immediately will result in a large percentage of cures.

Hunt,[15] in 1939, discussed mediastinal abscess following esophageal injury and stated that early external drainage will result in low mortality, while untreated cases usually are fatal.

In 1944, Hoover[16] stated that "open drainage of the mediastinum is advocated for any rupture of the esophagus, perforation or mediastinitis as soon as diagnosed, except localized mediastinitis and periesophageal abscess which is draining into the pharynx from the esophageal lumen. In localized

mediastinitis, if the infection is draining about the perforating body and has been present for some days, extraction of the foreign body, administration of fluid and chemotherapy under careful observation will result in a large percentage of cures, but if at any time further spread of the infection is evident by the patient's symptoms, blood studies and Roentgenologic examination, surgical drainage should be carried out."

While these reports do not include all cases up to the present, they do show that no definite agreement as to procedure has been reached. With the advent of chemotherapy its employment may influence one to a more conservative approach; however, it would seem that the combination of early cervical mediastinotomy and chemotherapy offers the best chance for recovery.

## SURGICAL ANATOMY.

The surgical anatomy must take into consideration the three main compartments of the neck which are formed by the four layers of deep cervical fascia. These are: *1* Superficial. *2*. Pretracheal. *3*. Buccopharyngeal. *4*. Prevertebral. The three compartments formed by these layers are: *1*. Previsceral. *2*. Visceral. *3*. Retrovisceral. The visceral compartment is situated between the pretracheal and buccopharyngeal layers. It contains the thyroid gland, the trachea and esophagus. It is a very important space in the infection under consideration as it extends from the neck to the pericardium. The retrovisceral space lies behind the pharynx and esophagus, between the buccopharyngeal and prevertebral fascia. It should be noted that the connection between the previsceral space and the anterior mediastinum is interrupted by a fascial septum from the pretracheal layer to the sternum, but the visceral and retrovisceral spaces are directly continuous with the posterior mediastinum.

The mediastinum has no fascial planes forming definite compartments. The usual subdivisions are the superior and the inferior, with the inferior being further subdivided into

anterior, middle and posterior. An imaginary plane divides the superior and inferior. This plane extends from the intervertebral disc between the fourth and fifth dorsal vertebrae to the junction of the manubrium with the gladiolus. This plane also denotes the upper border of the heart. The superior and the posterior mediastinum are traversed vertically by the esophagus, aorta, thoracic ducts, vagus, phrenic and sympathetic nerves.

This commonly accepted anatomical classification is artificial and gives no idea of the continuity between the mediastinal and cervical divisions; neither does it serve any useful surgical consideration. As pointed out by Neuhof and Jemerin,[17] the superior mediastinum should be divided, for surgical anatomical consideration, into anterior and posterior portions. The posterior division consists of the thoracic extension of the visceral and retrovisceral cervical spaces. The anterior division would thus consist of that portion of the superior mediastinum anterior to the extension of the pretracheal fascia.

## DIAGNOSIS.

In almost all cases there is a history of ingestion of a foreign body or instrumentation, or both. The onset of the symptoms is usually in precise relation to this history. There may be no available history, especially in a child, the first symptom being an advanced infection. Pain occurs as early as dysphagia. Swelling of the supraclavicular space with tenderness on palpation signifies periesophageal extension. Low grade fever is usually present and is a very important symptom. Roentgenologic study is necessary to recognize the evolution of acute mediastinitis. Emphasis must be placed on the fact that the stage of impending mediastinitis can and, indeed, must be recognized in order to reduce incidences of fatal mediastinitis. The diagnosis may have to be made by inference from indirect evidence. Finally, it may rest solely on Roentgen evidence.

## INDICATIONS FOR OPERATION.

According to Neuhof and Jemirin,[17] "the indication for operation is the diagnosis of a perforation of the esophagus regardless of the paucity of clinical manifestations or the degree of manifestation referable to infection. The outlook for cure obviously is far better when little or no evidence of mediastinitis exists. Indeed, there should be no mortality in cases of traumatic perforation of the cervical esophagus if operation is performed promptly after injury has been inflicted."

It can be argued that spontaneous recovery can occur after perforation of the esophagus. Undoubtedly this is true; however, unchecked spread of the infection is the common sequel to untreated traumatic perforation of the esophagus.

## OPERATION.

Local anesthesia is preferable and usually suffices. An incision is made along the anterior border of the sternomastoid muscle in the lower cervical region. The muscle is retracted laterally. This exposes the great vessels which are also retracted laterally. The ribbon muscles and trachea are exposed and retracted mesially. The anterior body of the omohyoid is retracted downward. The thyroid gland is next exposed and retracted upward. The lateral aspect of the cervical esophagus will now be visualized. Edema, inflammation or suppuration will be seen. There will be anatomical alterations due to the infection and the accurate disclosure of the retro- and paraesophageal compartments will offer some difficulty. The presence of pus will aid in localizing the correct plane. If Roentgenograms reveal extension up toward the base of the skull, blunt dissection is employed to open the suppurative tract to its full limit. In these traumatic cases nearly all infection will be prevertebral. The perforation should be visualized. If the diagnosis is made early and operation is prompt, incision and drainage to the site of perforation will suffice. If infection is extensive do not hesitate to make a counter-incision on the opposite side of the neck. This will establish thorough retroesophageal drainage. A fin-

ger passed into the abscess cavity and behind the esophagus will be adequate guide for the counter-incision. If the infection has extended into the mediastinum, the cervical abscess is packed with gauze and the downward path enlarged. The esophagus is retracted forward and the mediastinum entered by blunt dissection. The pus encountered is suctioned carefully. Even if the abscess extends as far as the aorta, it can be drained adequately through the neck incisions. Two rubber tubes are placed in the abscess cavity. These not only facilitate the drainage, but also can be used for two-way irrigation. The foot of the bed is elevated. As healing progresses these tubes are shortened and eventually entirely removed.

Vocal cord paralysis, especially left, is not uncommon as scar tissue forms, which impinges on the recurrent laryngeal nerve. This will be permanent.

## CASE REPORTS.

*Case 1:* Mrs. M. Age 56. This edentulous patient choked while eating chicken salad. This was followed by lower throat discomfort and 24 hours later she consulted her physician. He advised eating coarse foods, and to report the condition the next day. Symptoms persisted, and three days after the choking, esophagoscopy was done. A small bone was removed from the cervical esophagus, and an area of localized infection was noted on the left wall. This case occurred prior to sulfonamide therapy. The next day pain and dysphagia persisted, and the temperature was elevated one degree. Roentgen studies showed periesophageal abscess and evidence of mediastinal infection. External drainage was established, and a large mediastinal abscess found. Two rubber tubes were placed in the abscess, and frequent gentle irrigation with neoarsphenamine solution was done. Feeding tube was passed and patient placed in bed with foot of bed elevated. The tubes were gradually shortened, and after 30 days healing was complete. The patient gained 10 pounds during the 30 days. There was a complete paralysis of the left vocal cord.

*Case 2:* Mrs. G. Age 50. This patient was also edentulous and choked severely while eating chicken salad. She immediately called her physician, who endeavored for an hour to remove or dislodge the bone. Being unsuccessful, he advised eating coarse food. Her condition became rapidly worse and two days later she was removed to the hospital. At admission she had a temperature of 102°; swallowing was impossible, there was marked dyspnea and tenderness over the supraclavicular area on the left side. Roentgen study revealed a huge retropharyngeal abscess and marked mediastinal widening. External cervical mediastinotomy was done, and a large amount of foul pus obtained. We were now able to do an esophagoscopy, removing the bone and finding two large perforations of the posterior wall. Progress was not satisfactory and two days later, counter-drainage was established from a localized abscess on the right side. General improvement ensued until the end of the third

week when a rise in temperature to 104° indicated the beginning basal meningitis which proved fatal. Autopsy revealed a well walled off mediastinal abscess cavity located in the superior posterior mediastinum, and three perforations of the esophagus. This case also occurred prior to sulfonamide therapy.

Fig. 1. Case 1. X-ray taken three days after chicken bone lodged in cervical esophagus.

*Case 3:* Mr. E. Age 73. Chief complaint was moderate persistent dysphagia. Roentgen studies of the esophagus were indefinite but for advanced cervical arthritis. An esophagoscopy was requested. This examination revealed a new growth at the cricopharyngeus. This growth was smooth, soft and of a bluish color. It was entirely submucosal; however, a biopsy was taken and powdered sulfathiazole gm. 0.5 placed on the tongue every three hours. Sterile fluids were employed. Forty-

Fig. 2. Case 2. Very extensive retropharyngitis and periesophagitis. Forty-eight hours after trauma from chicken bone and blind bouginage.

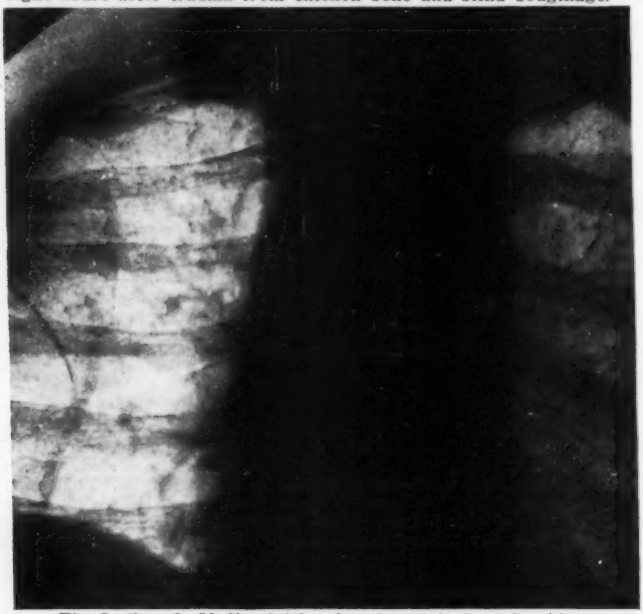

Fig. 3. Case 2. Mediastinitis, phrenic paralysis right side.

eight hours later there was moderate tenderness on deep pressure on the lower neck. No temperature or dysphagia. The patient insisted on his discharge and was permitted to go home, but ordered to report his condition daily. Nothing was heard from him until the fifth day when he stated he was expectorating considerable foul pus. Examination

Fig. 4. Case 2. Iodized oil in postmediastinum delineating large abscess cavity.

revealed a tender swelling above the clavicle on the left side. Readmission to the hospital and external cervical drainage was established. A large amount of foul pus was located in the retroesophageal space. No feeding tube was used. Rubber tubes were inserted and irrigation with potassium permanganate 1-10,000 done three times a day. The powdered sulfathiazole had been used since the esophagoscpy. Healing occurred rapidly and was complete in 10 days. The biopsy report was aberrant

thyroid gland. Perhaps one is justified in assuming that the sulfathiazole aided in the localization of the infection.

*Case 4:* Mrs. S. Age 64. While eating chicken salad patient choked severely. She stated that she could feel the bone and attempted to cause emesis by placing her finger in her throat. This act occurred at the evening meal. The patient was seen the next morning. At this time she was unable to swallow fluids. Her temperature was 101°. Roentgen study revealed very extensive retropharyngeal involvement with the offending foreign body appearing in the retropharyngeal space. Imme-

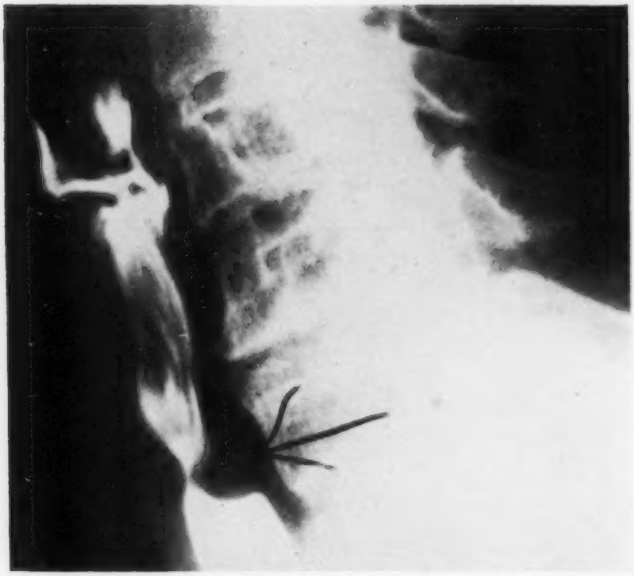

Fig. 5. Case 3. Contrast media in esophagus showing enlargement of cricopharynx, which contained an aberrant thyroid gland.

diate drainage was made by a midpharyngeal incision. Very small amount of pus was obtained, but swallowing and breathing were much improved. Adequate chemotherapy was instituted. Laboratory examination showed blood sugar of 385, 4+ albumin, blood pressure, 210/110. Roentgen study of chest showed no mediastinal involvement but a large hypertensive heart and bronchopneumonia. The diabetic condition responded satisfactorily. The retropharyngeal swelling subsided and the patient was able to take nourishment by mouth; however, three days later there was fatal cardiac failure.

## SUMMARY.

Early esophagoscopy is absolutely essential.

Early mediastinotomy in all cases that do not show rapid improvement.

Adequate chemotherapy, especially powdered sulfonamides placed on tongue. This will build up a high local concentration in the hypopharynx and upper esophagus.

Fig. 6. Case 3. Extensive mediastinitis. Feeding tube in place. Drainage tube in postmediastinum.

By following the above regimen it is believed that the mortality rate will be very much reduced.

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23 Kraft Avenue.

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## GEORGETOWN UNIVERSITY POSTGRADUATE COURSE.

The Georgetown University Medical Center will sponsor an intensive graduate course in oto-rhino laryngology-bronchoscopy by Prof. Georges Portmann, of the University of Bordeaux, France. The course will begin April 7, 1947, and continue for two weeks in Georgetown Medical School, Washington, D. C. Address inquiries to: James A. Flynn, M.D., F.A.C.S., 1511 Rhode Island Avenue, N.W., Washington, D. C.

# THE DEVELOPMENT OF RECORDED AUDITORY TESTS FOR MEASURING HEARING LOSS FOR SPEECH.[1]

C. V. HUDGINS,[2] J. E. HAWKINS,[3] J. E. KARLIN[4] and S. S. STEVENS,[5]
Boston, Mass.

## INTRODUCTION.

The loss of hearing for speech can be measured in decibels in a manner similar to that used to determine the hearing loss for pure tones (audiograms). The essential reguirements are *a.* adequate test materials, *b.* suitable equipment, and *c.* an established normal threshold based upon a group of listeners known to have normal hearing. This report describes two recorded Auditory Tests identical in design, but differing in the nature of the test items. Both tests measure the loss of hearing for speech by the simple device of comparing the thresholds of hearing of persons having impaired hearing with an average threshold obtained from normal hearing indidividuals. In one test the test items are words; in the other, short sentences.

In order to estimate the loss of hearing for speech it is sufficient that, for a given playback system and testing situation, an attenuation value relative to a standard playback level be established at which a hard-of-hearing listener obtains a score of 50 per cent correct for the test items. This value is arbitrarily called the threshold of hearing for speech. This threshold is then compared with an average threshold similarly obtained from a group of listeners known to have nor-

1. This research was initiated at the Psycho-Acoustic Laboratory, Harvard University, under contract OEMsr-658 with the Office of Scientific Research and Development, supervised by NDRC Section 17.3. The work has been completed under Contract N5ori-76 between the Office of Naval Research, U. S. Navy, and Harvard University (Report PNR-26).
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3. Now with Merck Institute for Therapeutic Research, Rahway, N. J.
4. Now at Bell Telephone Laboratories, Murray Hill, N. J.
5. Director, Psycho-Acoustic Laboratory, Harvard University.
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mal audiograms. The difference between the two thresholds is the loss of hearing for speech. This objective may be achieved satisfactorily, even though nothing is known of the absolute speech intensities involved. The essential thing is to measure in decibels, under identical conditions, the difference in intensity levels at which speech samples are just intelligible to normal and to defective ears.

## ESSENTIAL CHARACTERISTICS OF THE TEST MATERIALS.

Certain basic criteria are deemed essential as a guide in the selection of items (spoken words or sentences) for an audiometric test. These criteria are:

1. Familiarity.
2. Phonetic dissimilarity.
3. Normal sampling of English speech sounds.
4. Homogeneity with respect to basic audibility.

### *1. Familiarity.*

The necessity for the selection of familiar words and language forms is obvious. Since the object of the test is to measure the threshold of intelligibility for speech, rather than vocabulary or intelligence, it is essential that the items be as simple and familiar as possible within the requirements imposed by the other criteria.

### *2. Phonetic Dissimilarity.*

Phonetic dissimilarity among items is important because the presence of similar or rhyming words in the list imposes a type of auditory discrimination which serves no useful purpose in threshold tests. For instance, the inclusion in a test list of words that differ only with respect to a single sound, such as *plowboy* and *cowboy*, or *eyeball* and *highball*, increases its difficulty by demanding a finer discrimination, but does not increase the effectiveness of the test as an instrument for measuring the threshold for common English speech.

*3. Normal Sampling of English Sounds.*

A normal representation of English speech sounds is of less importance than the other criteria. It is included in the list of desiderata and is adhered to with a reasonable fidelity in the selection of items for the tests described in this paper, because it offered no serious restrictions in the selection of materials, and because the assumption is commonly made that in order to test hearing for speech all speech sounds must be presented as stimuli. While it is true that this becomes an important criterion in the construction of word lists for testing some types of auditory discrimination, or for testing communication equipment under certain conditions, there is ample evidence that a complete representation of English sounds is not essential in threshold measurement. For instance, the Western Electric 4C Test (see below) when used with high-fidelity playback equipment gives a reliable measure of hearing loss in spite of the fact that the seven digits which make up the test contain only seven vowels and nine consonants.

*4. Homogeneity with Respect to Basic Audibility.*

The audibility of words or sentences may be defined as the relative ease with which they are understood when they are spoken at a constant level by a normal talker. Under these conditions the threshold of intelligibility for different words might vary from 5 to 15 db., depending upon the number of syllables, the phonetic content, and the stress pattern.

In order to ensure homogeneity in a word list, two procedures are possible. *1.* We can choose for the list only those words which, when spoken in a normal tone of voice, tend to reach the listener's threshold at the same level of amplification. *2.* We can so adjust the level at which the individual words are recorded that they tend all to be heard at the same level of reproduction. Or, as a matter of fact, we can combine these two procedures in order to maximize homogeneity.

Homogeneity is important for two reasons: First, it increases the probability that the function relating the percentage of items heard correctly and the intensity levels at

which they are presented to the listeners will rise steeply from zero to 100 per cent within a narrow range of intensity. Given a constant amount of random error in the testing procedure, it follows that the steepness of this function determines the precision with which the threshold for the test (the 50-per-cent level) can be estimated from the plot (see Fig. 1). Second, it is desirable to determine the threshold of hearing for speech with the use of as small a number of items as possible. A list of homogeneous items can be subdivided into small groups with the assurance that the subgroups are equivalent with respect to audibility. Hence, threshold measurements can be obtained by presenting to listeners the subgroups of items in progressively decreasing steps of intensity. The corresponding decrement in articulation scores for the successive subgroups can then be attributed to differences in intensity level rather than to differences in the basic audibility of the individual items.

## PREVIOUS RECORDED TESTS FOR MEASURING HEARING LOSS FOR SPEECH.

An early recorded test was developed by Bryant* in 1904. The test did not receive wide usage probably because of the relative crudeness of phonographic equipment of that day. The test was composed of selected monosyllables recorded on wax cylinders at a constant level. The playback system was a mechanical phonograph enclosed in a soundproof box from which the acoustic signals were led to the listener's ear by means of a tube. A control valve in the tube regulated the intensity of the signal by varying the diameter of the tube; thus, the hearing loss could be expressed in terms of the difference in degrees of valve opening at the threshold of normal and defective ears.

The first widely used recorded auditory test for determining hearing losses for speech was developed by the Bell Telephone Laboratories with the cooperation of the American Federation of Organizations of the Hard of Hearing in 1926. The test became known as the Western Electric 4A (now 4C)

*Bryant, W. S.: A Phonographic Acoumeter. Arch. Otol., 33:438-443, 1904.

Audiometer and has been described by Fletcher.* The test items are spoken digits. In the earlier form the digits were spoken in groups of three, in the latest version (Western Electric 4C Audiometer) the digits are spoken in pairs. The intensity of the recorded speech decreases in steps of 3 db. as the record progresses. The total range of the record is about 33 db.

The 4C Audiometer is designed as a group screening test and has been used in public schools throughout the country. It consists of a fixed-gain spring-powered phonograph with an electromagnetic reproducer. The level of the speech at the listeners' ears is such that normal ears in a quiet classroom situation are able to understand all except the last one or two pairs of digits in the series of 12. Thus, the test will estimate the hearing loss of ears which have losses ranging from 0 to 30 db. For testing more severe cases of deafness Fletcher suggests an amplifier and an attenuator to be interposed between the reproducer and the earphones. For this purpose a record is supplied with the items recorded at a constant level. By means of the attenuator the speech intensities delivered to the ear can be varied by any desired amount.

The 4C Audiometer has many merits. The simplicity of the standard equipment offers no technical problems for its administration. Since the instrument can be equipped with as many as 40 earphones, it is possible to test large groups at once. No specially sound-treated room is required for its use. The familiarity of the test items (spoken digits) renders it possible to test pupils in the lowest primary grades. The test is easily scored by means of prepared forms and a scoring stencil.

The limitations of the 4C lie largely in the limited range covered by the fixed-gain playback equipment and the relatively few speech sounds sampled. In its standard form the 4C Audiometer is admittedly not a precision instrument and the 33-db. range limits its usefulness to that of a coarse screening device. The items of the test are made up of the

*Fletcher, H.: Speech and Hearing. New York, Van Nostrand Co., 1929, pp. 211-214.

seven digits: one, two, three, four, five, six, and eight. Since no particular vowel occurs more than once in this series, recognition depends almost solely upon the identification of individual vowels rather than upon consonants. This, however, it not a serious limitation in measuring the hearing loss for speech unless we are concerned with the diagnosis of high-frequency hearing loss. Test items which are recognized by vowel content alone will not differentiate between an ear having a uniform hearing loss and one having a severe high-tone loss.

## THE EXPERIMENTAL PROGRAM.

A program of audiometric test development was undertaken at the Psycho-Acoustic Laboratory with three aims in view:

*1.* To explore further the problems involved in the construction of audiometric tests for measuring directly the hearing loss for speech.

*2.* To produce a test suitable for precise laboratory measurements of all degrees of hearing loss.

*3.* To explore by means of verbal tests the possibility of differentiating between high-frequency deafness and deafness which is uniform throughout the audible frequency range.

The results of our study of the first objective are summarized in the previous pages.

Our struggles toward the second objective are described more fully below. Two tests,* Auditory Test No. 9, Threshold of Hearing for Words, and Auditory Test No. 12, Threshold of Hearing for Sentences, were developed to satisfy the need for a precise verbal instrument for assessing hearing losses. Both tests measure hearing losses for speech with a precision as great as or greater than that possible in the measurement of losses for pure tones. With relatively simple playback equipment it is possible to measure losses of hearing for speech over the total intensity range encompassed by the human ear.

*Phonographic recordings of these tests may be obtained from Central Institute for the Deaf, 818 South Kingshighway, St. Louis 10, Mo.

The problem posed by the third objective, the development of a test for high-frequency deafness, is complicated by the existence of different types and degrees of high-frequency hearing loss. For our present purposes, however, we may regard pure-tone audiograms as indicative of two general types of high-frequency losses: *a.* The loss may increase progressively, but relatively uniformly, for successive frequencies. The audiogram of a patient with this type of loss reveals a sloping curve which descends from low to high frequency at rates varying from 5 to 15 or more decibels per octave. *b.* The other type of hearing loss may be uniform over the low frequencies but may cut off abruptly at some point above about 1,000 cps. The degree of abruptness of the cutoff also varies in this type of loss.

Unless a test can be devised which is relatively simple to administer and at the same time precise, it may be expected to show no special advantage over the pure-tone audiometer as a device for differentiating between uniform and high-frequency losses.

There are two approaches to the problem: *a.* the development of a test composed of highly selected items which contain only the so-called high-frequency consonants and vowels, and *b.* the development of a test composed of items which contain a normal sampling of English sounds, but given, in the process of recording, a high-frequency pre-emphasis by means of a high-pass filter network. We have tried both types of test in our experimental program, but the second proved to be the more discriminating for high-frequency losses.

In its most promising form the test utilizing pre-emphasis revealed significant differences between: *a.* uniform deafness and high-frequency deafness of the uniformly sloping type, provided the slope was greater than 5 or 6 db. per octave, *b.* uniform deafness and deafness showing a high-frequency cutoff, providing the cutoff occurred below 3,000 cps. This latter limitation is not surprising, for it is well known that a person whose hearing is normal up to 3,000 cps. ordinarily understands human speech without difficulty. As a matter of

fact, most modern telephone receivers pass only frequencies below 3,000 cps.

The items in the high-frequency test were the same as those used for Auditory Test No. 9. The "high-frequency" character of the test was achieved by the insertion of a 4,000-cycle high-pass filter (United Transformer Corp., Type 4C) into the recording system. The filter attenuates frequencies below 4,000 cps. at the rate of 17 db. per octave. Thus, the speech sounds at, for example, 500 cps. are reduced by 51 db. below their relative level in normal speech. The filtered speech, with its pre-emphasis of the higher tones, forces the listener to depend more than normally upon the higher frequencies for perceptive cues with the result that, for persons with a high-tone hearing loss, a relatively higher intensity level is needed to reach the threshold of speech perception.

It is our opinion that, in its present form, the high-frequency test offers no real advantage over the pure-tone audiometer as a diagnostic instrument. We believe that the hearing loss for normal speech, which has a theoretical as well as a clinical value, can be adequately and quickly measured by means of either of the two tests described below, and that the problem of differentiating between the several types of deafness can at present be handled most efficiently by the pure-tone audiometer. The two sets of data, the hearing loss for speech and the losses for various pure tones, provide a reasonably complete picture of the patient's auditory handicap.

Consequently, the remainder of this paper is concerned with descriptions of the two auditory tests based on normal, undistorted speech.

### AUDITORY TEST NO. 9: THRESHOLD OF HEARING FOR WORDS.

This test consists of two lists of 42 dissyllabic words of the *spondee* stress pattern, *i.e.*, words such as *blackbird, railroad,* in which both syllables are equally accented.

Spondees were chosen for the test items after a large pool of dissyllabic words had been tested on normal-hearing listen-

ing crews. They were found to have a uniformly high audibility, which made it possible to select from among them a group of homogeneous items. The high audibility of the *spondee* as compared to other dissyllabic words, such as the *trochee* or *iamb*, is due apparently to the differences in stress pattern. Since both syllables of the spondee are equally stressed, auditory cues from each syllable are equally available to the ear. In contrast, the single accented syllables of trochees (*fa*ther, *wa*ter) and of iambs (up*on*, e*quip*) are more

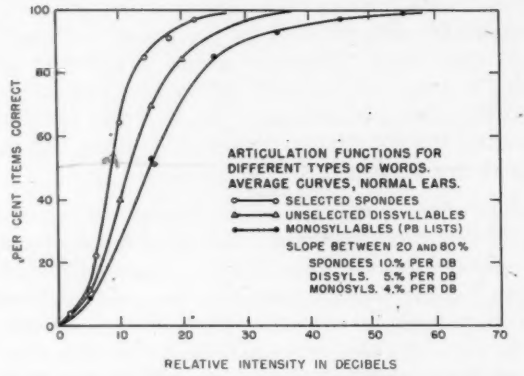


Fig. 1. Showing how the steepness of articulation functions depends on the kind of words used in the test. The number of words heard correctly is plotted against the relative level at which they are transduced by the earphones. The threshold of intelligibility, defined as the intensity level at which 50 per cent of the words are heard correctly, is more precisely determined when the articulation function is steep.

audible than the weaker, unstressed syllables, and the intelligibility of the words depends in part at least upon the cues from the weaker syllables. Monosyllabic words tend to show an even greater lack of uniformity. Factors such as phonetic content, and the greater possibility for similarity (rhyme) seem to affect their relative difficulty.

Fig. 1 shows three articulation functions obtained from normal hearing subjects who were tested with selected spondees (Auditory Test No. 9), with unselected dissyllabic words,

and with phonetically balanced monosyllables. The points on the curves represent the following data:

1. Selected spondees: the averages for ten normal listeners, each tested with six recordings of the same 42-word lists in rescrambled form.

2. Unselected dissyllables: the averages for four normal listeners, each tested with the same 50-word list read in rescrambled forms at different intensity levels.

3. Monosyllables: the average scores for four normal listeners, each hearing from three to five 50-word lists equated for difficulty and for consonant and vowel content (PB lists). The equivalence of difficulty among the PB lists is best shown by the fact that the standard deviation of a distribution of scores obtained by reading the PB lists to a crew of trained listeners is about five score units.

The slope of the curves is an indication of the relative homogeneity of the difficulty within the three types of materials. The steeper the slope, the greater the degree of homogeneity. The curve for the selected spondees has an average slope of 10 per cent per decibel over the range between 20 and 80 per cent. The curve for the monosyllables, on the other hand, has a slope of 4 per cent per decibel over the same range. The curve for the unselected dissyllables falls in between.

In the final recorded forms, each list of selected spondees (42 words in each of two lists) is recorded in six scrambled versions, making 12 equivalent forms of the test. The words are divided into seven groups of six words each, and each group is recorded at progressively lower intensity levels, 4 db. apart. Thus the range of levels on the records is 24 db. The words are recorded at six-second intervals, which allows time for writing them down. A carrier phrase, "Number One," "Number Two," etc., precedes each word, and at the lower recording levels the intensities of the carrier phrase is recorded at a higher level than that of the test item. A 1,000-cycle tone, to be used for setting the amplification for the playback system, is recorded on each disc.

The recording scheme is presented in the following tables:

| Words No. | Relative Level of Carrier Phrase | Relative Level of Test Words |
|---|---|---|
| 1- 6 | 0 db. | 0 db. |
| 7-12 | 0 db. | — 4 db. |
| 13-18 | 0 db. | — 8 db. |
| 19-24 | — 2 db. | —12 db. |
| 25-30 | — 6 db. | —16 db. |
| 31-36 | —10 db. | —20 db. |
| 37-42 | —14 db. | —24 db. |

The following order of lists appears on the six discs:

| |
|---|
| Record 9A, Side 1, List 1a |
| Record 9A, Side 2, List 1b |
| Record 9B, Side 1, List 1c |
| Record 9B, Side 2, List 1d |
| Record 9C, Side 1, List 1e |
| Record 9C, Side 2, List 1f |
| Record 9D, Side 1, List 2a |
| Record 9D, Side 2, List 2b |
| Record 9E, Side 1, List 2c |
| Record 9E, Side 2, List 2d |
| Record 9F, Side 1, List 2e |
| Record 9F, Side 2, List 2f |

The recording scripts are presented in the Appendix.

### AUDITORY TEST NO. 12: THRESHOLD OF HEARING FOR SENTENCES.

This test consists of eight lists of short, simple questions, each of which can be answered with a single word. The lists are composed of 28 items divided into seven groups of four items each. Each group of items is recorded at an intensity level 4 db. lower than the preceding one, yielding a total range of 24 db. The single exception to this is List 1, which is included on the record containing the verbal instructions. List 1 contains 21 items divided into seven groups of three items each, and each group is recorded at an intensity level 6 db. lower than the preceding group, a total range of 36 db. The record containing List 1 is especially useful in that it provides a screening method to determine the intensity level at which Lists 2-8 should be given.

Homogeneity for the sentences was achieved by the second of the two methods mentioned above, *i.e.*, by adjusting the level at which the individual sentences were recorded. First, the sentences were recorded at a constant level. The records were then replayed to normal listeners beginning at a level at which no sentence could be understood. The level was increased in subsequent repetitions in steps of 2 db. until all the sentences had been understood by each listener. From the scores thus obtained the level at which the average sentence was intelligible to normal listeners was determined. The deviation in decibels from this average became the amount by which it was necessary, in the process of re-recording the sentence, to raise or lower the level of the individual sentences. Then the systematic drops in steps of 4 db. in intensity level across the record were added in the final recordings.

A 1,000-cycle tone, to be used for setting the amplification of the playback system, was recorded on each of the records.

The recording scheme is presented in the following table:

LIST 1.

| Sentence No. | Relative Level of Carrier Phrase | Relative Level of Test Item |
|---|---|---|
| 1- 3 | 0 db. | 0 db. |
| 4- 6 | 0 db. | — 6 db. |
| 7- 9 | — 2 db. | —12 db. |
| 10-12 | — 8 db. | —18 db. |
| 13-15 | —14 db. | —24 db. |
| 16-18 | —20 db. | —30 db. |
| 19-21 | —26 db. | —36 db. |

LISTS 2-8.

| Sentence No. | Relative Level of Carrier Phrase | Relative Level of Test Item |
|---|---|---|
| 1- 4 | 0 db. | 0 db. |
| 5- 8 | 0 db. | — 4 db. |
| 9-12 | 0 db. | — 8 db. |
| 13-16 | — 2 db. | —12 db. |
| 17-20 | — 6 db. | —16 db. |
| 21-24 | —10 db. | —20 db. |
| 25-28 | —14 db. | —24 db. |

The following order lists appears on the four discs:

| Record | Side | List |
|---|---|---|
| 12A | 1 | 1 |
| 12A | 2 | 2 |
| 12B | 1 | 3 |
| 12B | 2 | 4 |
| 12C | 1 | 5 |
| 12C | 2 | 6 |
| 12D | 1 | 7 |
| 12D | 2 | 8 |

The recording scripts are presented in the Appendix.

## RELIABILITY OF THE TESTS.

Two types of errors are common to most testing situations. These are: *a. constant errors,* including those resulting from practice effects, and *b. random errors,* or errors of sampling resulting from uncontrolled factors in the test situation.

If a listener, incapable of learning, should be given the same auditory test a large number of times, his threshold of hearing for speech determined from the average of an ever lengthening series of tests should approach some value more and more closely. This value is called the *true score.* The degree to which a single test score approximates this true score determines the reliability of the test. Reliability is commonly expressed in terms of the *standard error of measurement.* This statistic is an estimate, variously derived, of the standard deviation that would result from a long series of repeated tests on the same unlearning subject. Using a suitable estimate of this quantity it is possible to determine the limits within which a listener's true score can be expected to fall when the only available measure of his performance is a score of a single test. When these limits are narrow relative to the differences found among individual listeners, the test is considered reliable; when broad, it is considered unreliable.

Fortunately, the constant error introduced by learning into repeated administrations of most tests does not seem to be present in these auditory threshold tests. At least, no significant improvement was shown in the mean scores of normal listeners during the administration of six forms of Test 9

and eight forms of Test 12. Some small differences were found in the level of the test records, but after these small differences were compensated for, the remaining variations in test scores could be considered random errors. These small fluctuations in score from one test to another are due to uncontrollable factors in the testing situation, such as variations in the listener's effort and minor distractions.

On the assumption that every score in the series and every listener in the group are equally subject to such errors, the scores of a number of listeners on a series of tests can be subjected to an analysis of variance, and a stable estimate obtained of the standard deviation of the random fluctuations. This measure, if the above assumption is satisfied, is the standard error of measurement.

In the case of Auditory Test No. 9, the standard error of measurement obtained from 30 normal subjects tested at the Psycho-Acoustic Laboratory under very favorable conditions was 2 db. A group of 37 normal subjects tested at a U. S. Navy installation under rather less favorable conditions showed a standard error of measurement of 2.4 db. Since the less favorable conditions are more likely to obtain in all except strictly laboratory conditions the figure derived from the Naval group is probably a better estimate of the standard error of measurement under clinical conditions.

Similarly, the test was administered to three groups of hard-of-hearing subjects totalling 70 in all. Twenty-eight of these were aural casualties tested in an Army rehabilitation hospital, 17 were tested in an otological clinic in a large city hospital, and 25 were tested in this laboratory. The standard error of measurement for the three groups ranged from 2.1 to 2.8 db.

We can conclude, therefore, that a single administration of Test 9 to normal or hard-of-hearing subjects will, two-thirds of the time, give a score that falls within 2.8 db. of the subject's true score on that form of the test. The last restriction is necessary because the different forms of the test may be slightly different in level. We have observed in this connec-

tion that the recorded level of List 1d of Test No. 9 appears to be as much as 2 db. lower than the others. The other lists appear to be entirely interchangeable.

In the case of Auditory Test No. 12 the standard errors of measurement obtained from two groups of 16 and 52 normal subjects were 2.8 and 2.2, respectively. Two groups of 21 and 28 hard-of-hearing subjects tested at this laboratory and at an Army Rehabilitation Center yielded standard errors of measurement of 2.3 and 1.4 db., respectively.

We can conclude in the case of Auditory Test No. 12 that a single administration of a single form of the test will two-thirds of the time give a score that falls within 2.8 db. of the true score of that form of the test. Again, this latter restriction is necessary because there are slight differences in the recorded level of some of the forms of the test. These differences have been noted and equated pairs of test forms are listed below.

## INSTRUCTIONS FOR ADMINISTERING THE TESTS.

The following suggestions apply equally to both Test No. 9 and Test No. 12 since the tests are identical in design and purpose. They may be used to test groups in which the listeners write down the responses or to test subjects individually. They may be administered by earphone or by loudspeaker.

*1. Equipment.*

The playback system should have the following characteristics:

*Turntable:* 78 revolutions per minute.

*Pickup:* Light weight (1 to 2 ounces); a frequency characteristic which is reasonably flat from 100 to 4,000 cps.

*Amplifier:* A uniform frequency characteristic between 100 and 4,000 cps.; a minimum of distortion and hum; sufficient power to drive a loudspeaker or the number of earphones used, on the basis of 50 milliwatts per phone. The amplifier input should be able to operate at a fairly high input level without overloading. Otherwise a high-impedance attenuator may be needed between the pickup and the amplifier input.

*Voltmeter:* A reasonably good AC voltmeter which will insure that the appropriate playback level is being used.

*Attenuator:* A range of about 100 db., in steps of 1 or 2 db.; sufficient power-handling capacity. (Hewlett-Packard 5-watt, 500-ohm attenuator, Model 350-A, will usually be found adequate.)

*Matching Transformer:* A line-to-line transformer, with a number of different secondary impedance taps, should be used if necessary.

*Earphones:* A uniform frequency and impedance characteristic between 100 and 4,000 cps. Dynamic earphones, Type PDR-3 or PDR-8 (Permoflux Corp.), are recommended. They should be used with a tight fitting earphone cushion.

*Loudspeaker:* Reasonably uniform frequency characteristics between 100 and 4,000 cps. A good quality 12-inch dynamic speaker in a bass reflex cabinet will usually be found adequate.

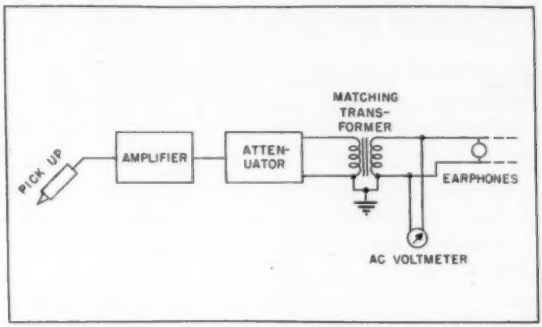


Fig. 2. Arrangement of the equipment for administering the auditory tests.

*2. Setting Up the Equipment.*

A quiet room is essential, for otherwise the lowest speech intensities will be masked, giving a spurious threshold. The turntable should be placed in an adjoining room or, at any rate, at such a distance from the listeners that they cannot hear directly the noises made by the pickup.

The block diagram (see Fig. 2) shows the arrangement of the apparatus. From the amplifier output the components are arranged in the following order: attenuator, matching transformer (if necessary), voltmeter, and earphones. If several earphones are used they should be matched for sensitivity and should be connected in parallel. The voltmeter may also be placed ahead of the attenuator if the voltmeter does not have sufficient sensitivity to read low levels of voltage.

In order to avoid "hum," it may be necessary to shield and ground the apparatus. If the amplifier has more than one gain control, choose a combination of settings that will give the least hum for the desired gain. If it has a tone control, see that it is set for flat response, *i.e.*, full on.

*3. Establishing the Threshold of Hearing for Speech.*

Thresholds are conveniently expressed in terms of decibels of attenuation relative to a standard voltage generated across the earphone by the 1,000 cycle tone recorded on each disc. A level of 1.0 volt generated across the earphones by the recorded tone on each disc is a convenient

standard for most practical situations. For testing normal listeners, however, it has been found convenient to set this voltage level at 0.1 volt instead of 1.0 volt in order to reduce the necessary amount of attenuation. The final average normal threshold, however, should be expressed in decibels of attenuation below 1.0 volt for convenience in calculating the losses for defective ears. The simple addition of 20 db. to the normal threshold value, as established for a level of 0 1 volt, provides the proper correction. Once the standard voltage level has been set, the attenuator setting is adjusted until the subject is able to obtain a score of 100 per cent on the first one or two levels on the record, and a score of 0 per cent on the last one or two levels. Somewhere in between, the subject will obtain a score of 50 per cent. The threshold of hearing is then calculated in decibels as the sum of the attenuator setting and the number-of-decibels drop across the record up to the point at which 50 per cent of the items are understood. Methods for determining the decibel drop across the record are given below.

Ordinarily one ear is tested at a time. In this case the headbands should be equipped with one active earphone with a snugly fitting cushion over the ear to be tested, and a dummy earphone with a similar cushion over the contralateral ear. The subjects should be provided with pencils and ruled paper with lines numbered 1 to 42 for Auditory Test No. 9, and 1 to 28 for Auditory Test No. 12. At the tops of the form space should be provided for the subject's name, date, test list, and the ear being tested. Subjects should be instructed somewhat as follows for Test No. 9:

> "You will hear a voice repeating a list of words. Each word will be preceded by the phrase, 'Number one, number two, etc.' As the record progresses this phrase will be spoken louder than the test word itself. This is to help you keep track of the words even when you cannot understand them. You are to write down each word opposite its number on the page. If you are not sure of a word, make a guess at it, but do not worry over a doubtful word so long that you miss the one following it. As soon as you hear the voice say 'Number so-and-so' abandon the previous word and listen attentively for the one coming. The words will sound fainter and fainter as the test progresses, but keep on trying to get them as long as you can hear the voice calling the number. When you can hear nothing more, sit quietly until the end of the record."

By way of further preparing the subjects for the test it may be found feasible to play one record over at a level well above the threshold in order to familiarize them with the type of test and material. If there is some question concerning the familiarity of the words it is good practice to give the subjects copies of the word lists in alphabetical order so that they may become more familiar with them.

The instructions for Auditory Test No. 12 are recorded on Record 12A. The items on this record may be used to establish the attenuation level for the test. Copies of the test sentences may not be given the subjects however, since memory might influence the threshold score.

It is advisable to use more than one list in seeking a reliable determination of the threshold. If the results of two lists yield similar threshold values (less than 4 db. apart) the average of the two is the best estimate of the threshold. If the values are 4 or more decibels apart, further lists should be given until the threshold is more reliably determined.

Certain minor differences in average difficulty among the different lists in Test 12 tend to introduce errors in average thresholds based upon a random selection of lists. In order to avoid such errors the eight forms have been paired in combinations which insure equivalence of difficulty. Average thresholds based upon the following paired lists proved to be a more nearly equivalent than those obtained from other combinations:

Lists 2 and 8
Lists 1 and 5
Lists 3 and 4
Lists 6 and 7

Since the hearing loss of the hard-of-hearing subject is to be expressed relative to that of a normal ear, it is first necessary to determine, with the particular equipment used, the average threshold (the level at which 50 per cent of the items are understood) for normal ears. Thresholds should be obtained from eight to ten subjects *who are known to have normal audiograms.* If the subjects have normal audiograms, their thresholds for speech will be found to be in close agreement. Hence the average threshold for eight to ten subjects should be sufficient to establish a norm with which deafened ears may be compared.

Step by step, the procedure for establishing thresholds for the tests may be summarized as follows:

*1.* Set up the playback system as shown in Fig. 2.

*2.* Match the earphone load to the attenuator output impedance, using a matching transformer or a resistive network. In order for the attenuator to be read in decibel units it must be either terminated or fed by its proper impedance. If the earphone load does not constitute a proper impedance match for the output of the attenuator it is generally advisable to use the matching transformer or network.

*Note:* If there remains a question of whether the attenuator has been properly matched to the load, a safe procedure is to make sure that the attenuator is always set for at least 10 db. attenuation. For values above 10 db. the attenuator will read essentially correctly regardless of the value of the load.

*3.* If the matching transformer is used there will also be a loss occasioned by transforming a voltage from a higher to a lower impedance. This loss may be ignored if the standardizing voltage is measured directly across the earphones. If the voltmeter is placed in front of the transformer, however, it will be necessary to convert the transformer loss to decibels of attenuation and to add this to the total attenuator setting. This loss may be calculated as follows:

$$\text{Decibel loss} = 10 \log_{10} \frac{Z_p}{Z_s}$$

where $Z_p$ is the impedance of the primary and $Z_s$ is the impedance of the secondary. For example, if the recommended earphones, Type PDR-3

or PDR-8 (normal impedance 300 ohms per phone) are used in parallel and matched by a transformer to a 500-ohm attenuator, the following losses occur across the transformer:

| No. Earphones in Parallel | Decibel Loss Across Transformer |
|---|---|
| 1 | 2 |
| 2 | 5 |
| 3 | 7 |
| 4 | 8 |
| 5 | 9 |
| 6 | 10 |

4. Adjust the amplifier so that the level of the recorded pure tone produces a known voltage across the earphone. Then adjust the attenuator until the subject's threshold falls within the range of speech levels recorded on the records. It is essential that the level be high enough for the subject to obtain a score of 100 per cent on at least the first speech level on the record.

For very deaf patients, removal of most of the attenuation may be insufficient to bring the speech signals up to threshold level, particularly if it is necessary to keep at least 10 db. in the attenuator in order to insure its proper function. For such patients, it may be necessary to readjust the amplifier. For these cases the decibel value of the threshold is determined by the total amount of attenuation plus the decibel change in voltage input to the earphone. The following table indicates the equivalent decibel increments, relative to 1.0 volt, for several voltages.

| Volts | Decibel Increment |
|---|---|
| 1.5 | 4 |
| 2 | 6 |
| 2.5 | 8 |
| 3 | 10 |
| 3.5 | 11 |
| 4 | 12 |

## SCORING THE TESTS.

*1. Threshold of Hearing for Speech.*

The tests are scored in terms of decibels of atenuation below the standardizing voltage. The first step in scoring is to determine the drop across the record up to the point at which a score of 50 per cent is obtained. It may be calculated in either of two ways.

*a. Graphical Method:* Make a plot relating the percentage correct to the levels on the record (0 to 24 db. for Auditory Test No. 9 and for Lists 2 to 9 of Auditory Test No. 12, and 0 to 36 db. for List 1, Test No. 12). From the plot determine the decibel drop across the record at which the curve crosses the 50-per-cent-correct point. Add this value to

the total attenuation in the system (attenuator setting*) to obtain the threshold value. The method is illustrated in Fig. 3.

*b. Tabular Method:* This method utilizes Tables 1 and 2 in the Appendix which give directly the decibel drop across the record for the two tests corresponding to the 50-per-cent point on the curve described in the graphical method. With the tabular method it is necessary only to total the number of items heard correctly, after which the corresponding decibel values of the 50-per-cent point is obtained automatically from the table. This value is then added to the total attenuation in the system.

*2. Hearing Loss for Speech.*

The subject's hearing loss is the difference between his threshold of hearing as determined by either of the methods described above and the

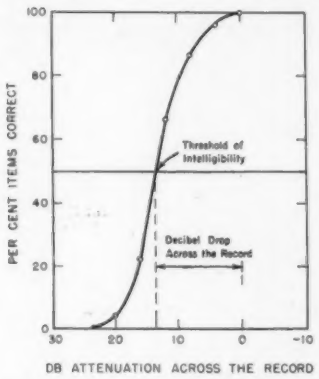


Fig. 3. Illustrating the use of a graphic plot for the determination of the threshold of intelligibility. From the curve drawn through the plotted points, the recorded attenuation corresponding to the 50 per cent score can be determined.

average threshold for a group of normal subjects. As a final step, therefore, subtract the decibel value obtained for the threshold of the subject from the decibel value obtained for the average threshold of a normal group in order to determine the subject's hearing loss in decibels. Fig. 4 summarizes the method.

## LOUDSPEAKER ADMINISTRATION.

The tests are equally adaptable for loudspeaker administration provided that:

1. The testing room is quiet, and the walls are treated with sound-absorbent material.

*If the voltage for the standardizing tone is read at the input to the attenuator instead of directly across the earphones the drop across the matching transformer must be added to the total attenuation.

2. Listeners are tested singly.

3. The listeners are maintained in a fixed position with respect to the loudspeaker.

In all other respects, the procedures for administering the tests are the same as for earphone administration.

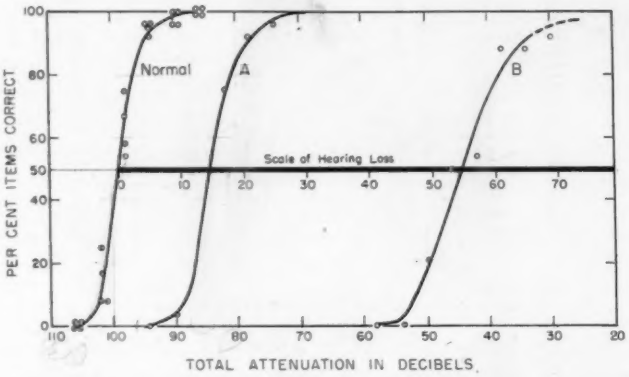


Fig. 4. Showing how the hearing loss for each of two subjects, A and B, is established in terms of the articulation function obtained from a group of normal listeners. Hearing loss is equivalent to the horizontal distance (in decibels) between the curve for the normal and that for the defective ear. Since the threshold is based on the score of 50 per cent correct, the horizontal line through the middle of the plot provides a scale of hearing loss.

## APPENDIX.

### TABULAR METHOD FOR SCORING AUDITORY TEST NO. 9: THRESHOLD OF HEARING FOR WORDS.

*Procedure:*

1. Count up the number of recorded test words correctly understood by the subject.

2. Determine from Table 1 the decibel value corresponding to this number of words.

3. Add this value to the number of decibels of attenuation in the playback system.

The result is a decibel value corresponding to the subject's threshold, defined as the level at which he is able to understand 50 per cent of the words. The subject's hearing loss is the difference between this value and the corresponding value for a group of normal hearing subjects.

TABLE 1.

| Words Correct | Decibel Values | Words Correct | Decibel Values |
|---|---|---|---|
| 6 | 2 | 23 | 13 |
| 7 | 3 | 24 | 14 |
| 8 | 3 | 25 | 15 |
| 9 | 4 | 26 | 15 |
| 10 | 5 | 27 | 16 |
| 11 | 5 | 28 | 17 |
| 12 | 6 | 29 | 17 |
| 13 | 7 | 30 | 18 |
| 14 | 7 | 31 | 19 |
| 15 | 8 | 32 | 19 |
| 16 | 9 | 33 | 20 |
| 17 | 9 | 34 | 21 |
| 18 | 10 | 35 | 21 |
| 19 | 11 | 36 | 22 |
| 20 | 11 | 37 | 23 |
| 21 | 12 | 38 | 23 |
| 22 | 13 | 39 | 24 |

RECORDING SCRIPT.

AUDITORY TEST NO. 9.

LIST 1a.

This is Test No. 1a.

Are you ready?

(0 db.) 1. sunset
2. whitewash
3. drawbridge
4. armchair
5. wildcat
6. birthday

(—4 db.) 7. bonbon
8. bloodhound
9. sidewalk
10. shipwreck
11. cupcake
12. cowboy

(—8 db.) 13. dovetail
14. earthquake
15. firefly
16. airplane
17. hedgehog
18. hardware

(—12 db.) 19. oatmeal
20. watchword
21. coughdrop
22. doorstep
23. woodwork
24. playground

(—16 db.) 25. bobwhite
26. shotgun
27. wigwam
28. hothouse
29. buckwheat
30. baseball

(—20 db.) 31. eggplant
32. eyebrow
33. stairway
34. railroad
35. headlight
36. mousetrap

(—24 db.) 37. outlaw
38. bagpipe
39. inkwell
40. blackboard
41. backbone
42. northwest

1,000-cycle tone

LIST 1b.

This is Test No. 1b.

Are you ready?

(0 db.) 1. bloodhound
2. shipwreck
3. bagpipe
4. cupcake
5. cowboy
6. wigwam
(—4 db.) 7. dovetail
8. earthquake
9. inkwell
10. airplane
11. hedgehog
12. hardware
(—8 db.) 13. oatmeal
14. watchword
15. blackboard
16. doorstep
17. woodwork
18. playground
(—12 db.) 19. bobwhite
20. shotgun
21. backbone
22. hothouse
23. buckwheat
24. baseball
(—16 db.) 25. eggplant
26. eyebrow
27. northwest
28. railroad
29. headlight
30. mousetrap
(—20 db.) 31. outlaw
32. whitewash
33. drawbridge
34. armchair
35. wildcat
36. birthday
(—24 db.) 37. sunset
38. stairway
39. sidewalk
40. firefly
41. coughdrop
42. bonbon

1,000-cycle tone

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LIST 1c.

This is Test No. 1c.

Are you ready?

(0 db.) 1. earthquake
2. firefly
3. northwest
4. hedgehog
5. hardware
6. stairway
(—4 db.) 7. oatmeal
8. watchword
9. bagpipe
10. doorstep
11. sunset
12. wigwam
(—8 db.) 13. bobwhite
14. shotgun
15. inkwell
16. hothouse
17. shipwreck
18. baseball
(—12 db.) 19. eggplant
20. eyebrow
21. blackboard
22. railroad
23. headlight
24. mousetrap
(—16 db.) 25. outlaw
26. whitewash
27. backbone
28. armchair
29. wildcat
30. birthday
(—20 db.) 31. bloodhound
32. sidewalk
33. airplane
34. cupcake
35. cowboy
36. dovetail
(—24 db.) 37. buckwheat
38. playground
39. bonbon
40. coughdrop
41. woodwork
42. drawbridge

1,000-cycle tone

LIST 1d.

This is Test No. 1d.
Are you ready?

| | | |
|---|---|---|
| (0 db.) | 1. watchword | |
| | 2. coughdrop | |
| | 3. inkwell | |
| | 4. woodwork | |
| | 5. playground | |
| | 6. airplane | |
| (—4 db.) | 7. bobwhite | |
| | 8. shotgun | |
| | 9. northwest | |
| | 10. hothouse | |
| | 11. drawbridge | |
| | 12. earthquake | |
| (—8 db.) | 13. eggplant | |
| | 14. eyebrow | |
| | 15. backbone | |
| | 16. railroad | |
| | 17. buckwheat | |
| | 18. mousetrap | |
| (—12 db.) | 19. outlaw | |
| | 20. whitewash | |
| | 21. armchair | |
| | | 22. headlight |
| | | 23. birthday |
| | | 24. doorstep |
| | | (—16 db.) 25. bonbon |
| | | 26. blackboard |
| | | 27. cupcake |
| | | 28. baseball |
| | | 29. cowboy |
| | | 30. bagpipe |
| | | (—20 db ) 31. dovetail |
| | | 32. firefly |
| | | 33. hedgehog |
| | | 34. birthday |
| | | 35. hardware |
| | | 36. sunset |
| | | (—24 db.) 37. oatmeal |
| | | 38. bloodhound |
| | | 39. stairway |
| | | 40. sidewalk |
| | | 41. wigwam |
| | | 42. shipwreck |

1,000-cycle tone

---

LIST 1e.

This is Test No. 1e.

Are you ready?

| | | |
|---|---|---|
| (0 db.) | 1. shotgun | |
| | 2. wigwam | |
| | 3. blackboard | |
| | 4. buckwheat | |
| | 5. baseball | |
| | 6. drawbridge | |
| (—4 db.) | 7. eggplant | |
| | 8. eyebrow | |
| | 9. backbone | |
| | 10. railroad | |
| | 11. mousetrap | |
| | 12. stairway | |
| (—8 db.) | 13. outlaw | |
| | 14. whitewash | |
| | 15. bagpipe | |
| | 16. headlight | |
| | 17. birthday | |
| | 18. shipwreck | |
| (—12 db.) | 19. sunset | |
| | 20. sidewalk | |
| | 21. cupcake | |
| | | 22. wildcat |
| | | 23. bonbon |
| | | 24. airplane |
| | | (—16 db.) 25. bloodhound |
| | | 26. firefly |
| | | 27. inkwell |
| | | 28. cowboy |
| | | 29. dovetail |
| | | 30. doorstep |
| | | (—20 db.) 31. earthquake |
| | | 32. coughdrop |
| | | 33. woodwork |
| | | 34. hardware |
| | | 35. oatmeal |
| | | 36. hothouse |
| | | (—24 db.) 37. watchword |
| | | 38. northwest |
| | | 39. hedgehog |
| | | 40. playground |
| | | 41. bobwhite |
| | | 42. armchair |

1,000-cycle tone

LIST 1f.

This is Test No. 1f.

Are you ready?

(0 db.) 1. firefly
2. shotgun
3. inkwell
4. wigwam
5. cowboy
6. blackboard

(—4 db.) 7. dovetail
8. buckwheat
9. doorstep
10. baseball
11. earthquake
12. drawbridge

(—8 db.) 13. coughdrop
14. eggplant
15. woodwork
16. eyebrow
17. hardware
18. backbone

(12 db.) 19. oatmeal
20. railroad
21. hothouse
22. mousetrap
23. watchword
24. stairway

(—16 db.) 25. bloodhound
26. northwest
27. outlaw
28. airplane
29. hedgehog
30. whitewash

(—20 db.) 31. bonbon
32. playground
33. bagpipe
34. wildcat
35. bobwhite
36. headlight

(—24 db.) 37. cupcake
38. armchair
39. birthday
40. sidewalk
41. sunset
42. shipwreck

1,000-cycle tone

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LIST 2a.

This is Test No. 2a.

Are you ready?

(0 db.) 1. cookbook
2. farewell
3. iceberg
4 mishap
5. pancake
6. horseshoe

(—4 db.) 7. toothbrush
8. woodchuck
9. yardstick
10. cargo
11. eardrum
12. housework

(—8db.) 13. midway
14. padlock
15. schoolboy
16. therefore
17. whizzbang
18. workshop

(—12 db.) 19. blackout
20. doormat
21. hotdog
22. grandson
23. outside
24. platform

(—16 db.) 25. sundown
26. scarecrow
27. beehive
28. duckpond
29. greyhound
30. lifeboat

(—20 db.) 31. nutmeg
32. playmate
33. starlight
34. washboard
35. although
36. daybreak

(—24 db.) 37. footstool
38. jacknife
39. mushroom
40. pinball
41. soybean
42. vampire

1,000-cycle tone

LIST 2b.

This is Test No. 2b.

Are you ready?

| | | |
|---|---|---|
| (0 db.) | 1. toothbrush | |
| | 2. midway | |
| | 3. blackout | |
| | 4. sundown | |
| | 5. nutmeg | |
| | 6. footstool | |
| (—4 db.) | 7. cookbook | |
| | 8. woodchuck | |
| | 9. padlock | |
| | 10. doormat | |
| | 11. scarecrow | |
| | 12. playmate | |
| (—8 db.) | 13. farewell | |
| | 14. yardstick | |
| | 15. schoolboy | |
| | 16. hotdog | |
| | 17. beehive | |
| | 18. starlight | |
| (—12 db.) | 19. iceberg | |
| | 20. cargo | |
| | 21. therefore | |
| | | 22. grandson |
| | | 23. duckpond |
| | | 24. washboard |
| | (—16 db.) | 25. mishap |
| | | 26. eardrum |
| | | 27. whizzbang |
| | | 28. outside |
| | | 29. greyhound |
| | | 30. although |
| | (—20 db.) | 31. pancake |
| | | 32. houeswork |
| | | 33. workshop |
| | | 34. platform |
| | | 35. lifeboat |
| | | 36. daybreak |
| | (—24 db.) | 37. horseshoe |
| | | 38. jacknife |
| | | 39. mushroom |
| | | 40. pinball |
| | | 41. soybean |
| | | 42. vampire |

1,000-cycle tone

---

LIST 2c.

This is Test No. 2c.

Are you ready?

| | | |
|---|---|---|
| (0 db.) | 1. woodchuck | |
| | 2. doormat | |
| | 3. jacknife | |
| | 4. scarecrow | |
| | 5. playmate | |
| | 6. whizzbang | |
| (—4 db.) | 7. farewell | |
| | 8. yardstick | |
| | 9. mushroom | |
| | 10. hotdog | |
| | 11. beehive | |
| | 12. starlight | |
| (—8 db.) | 13. iceberg | |
| | 14. cargo | |
| | 15. pinball | |
| | 16. grandson | |
| | 17. duckpond | |
| | 18. washboard | |
| (—12 db.) | 19. mishap | |
| | 20. eardrum | |
| | 21. soybean | |
| | | 22. outside |
| | | 23. greyhound |
| | | 24. although |
| | (—16 db.) | 25. pancake |
| | | 26. housework |
| | | 27. vampire |
| | | 28. platform |
| | | 29. lifeboat |
| | | 30. daybreak |
| | (—20 db.) | 31. horseshoe |
| | | 32. midway |
| | | 33. blackout |
| | | 34. sundown |
| | | 35. nutmeg |
| | | 36. footstool |
| | (—24 db.) | 37. toothbrush |
| | | 38. workshop |
| | | 39. padlock |
| | | 40. schoolboy |
| | | 41. therefore |
| | | 42. cookbook |

1,000-cycle tone

LIST 2d.

This is Test No. 2d.

Are you ready?

| | | |
|---|---|---|
| (0 db.) | 1. yardstick | 22. platform |
| | 2. schoolboy | 23. lifeboat |
| | 3. vampire | 24. daybreak |
| | 4. beehive | (—16 db.) 25. horseshoe |
| | 5. starlight | 26. midway |
| | 6. workshop | 27. soybean |
| (—4 db.) | 7. iceberg | 28. sundown |
| | 8. cargo | 29. nutmeg |
| | 9. jacknife | 30. footstool |
| | 10. grandson | (—20 db.) 31. woodchuck |
| | 11. toothbrush | 32. padlock |
| | 12. whizzbang | 33. hotdog |
| (—8 db.) | 13. mishap | 34. scarecrow |
| | 14. eardrum | 35. playmate |
| | 15. mushroom | 36. farewell |
| | 16. outside | (—24 db.) 37. greyhound |
| | 17. doormat | 38. washboard |
| | 18. although | 39. cookbook |
| (—12 db.) | 19. pancake | 40. therefore |
| | 20. housework | 41. duckpond |
| | 21. pinball | 42. blackout |

1,000-cycle tone

---

LIST 2e.

This is Test No. 2e.

Are you ready?

| | | |
|---|---|---|
| (0 db.) | 1. cargo | 22. lifeboat |
| | 2. therefore | 23. nutmeg |
| | 3. mushroom | 24. grandson |
| | 4. duckpond | (—16 db.) 25. cookbook |
| | 5. washboard | 26. pinball |
| | 6. hotdog | 27. scarecrow |
| (—4 db.) | 7. mishap | 28. although |
| | 8. eardrum | 29. playmate |
| | 9. vampire | 30. jacknife |
| | 10. outside | (—20 db.) 31. farewell |
| | 11. blackout | 32. schoolboy |
| | 12. yardstick | 33. beehive |
| (—8 db.) | 13. pancake | 34. footstool |
| | 14. housework | 35. starlight |
| | 15. soybean | 36. toothbrush |
| | 16. platform | (—24 db.) 37. iceberg |
| | 17. greyhound | 38. woodchuck |
| | 18. daybreak | 39. workshop |
| (—12 db.) | 19. horseshoe | 40. padlock |
| | 20. midway | 41. whizzbang |
| | 21. sundown | 42. doormat |

1,000-cycle tone

LIST 2f.

This is Test No. 2f.
Are you ready?

| | | |
|---|---|---|
| (0 db.) | 1. eardrum | |
| | 2. whizzbang | |
| | 3. pinball | |
| | 4. greyhound | |
| | 5. although | |
| | 6. blackout | |
| (—4 db.) | 7. pancake | |
| | 8. housework | |
| | 9. soybean | |
| | 10. platform | |
| | 11. daybreak | |
| | 12. workshop | |
| (—8 db.) | 13. horseshoe | |
| | 14. midway | |
| | 15. jacknife | |
| | 16. lifeboat | |
| | 17. footstool | |
| | 18. doormat | |
| (—12 db.) | 19. toothbrush | |
| | 20. padlock | |
| | 21. scarecrow | |
| | 22. nutmeg | |
| | 23. cookbook | |
| | 24. hotdog | |
| (—16 db.) | 25. woodchuck | |
| | 26. schoolboy | |
| | 27. mushroom | |
| | 28. playmate | |
| | 29. farewell | |
| | 30. grandson | |
| (—20 db.) | 31. yardstick | |
| | 32. therefore | |
| | 33. duckpond | |
| | 34. starlight | |
| | 35. iceberg | |
| | 36. outside | |
| (—24 db.) | 37. cargo | |
| | 38. vampire | |
| | 39. beehive | |
| | 40. washboard | |
| | 41. mishap | |
| | 42. sundown | |

1,000-cycle tone

## TABULAR METHOD FOR SCORING AUDITORY TEST NO. 12: THRESHOLD OF HEARING FOR SENTENCES.

*Procedure:*

*1.* Count up the number of recorded test items correctly understood by the subject.

*2.* Determine from Table 2 the decibel value corresponding to this number of items. (Note that the table gives different values in separate columns for List 1, and Lists 2 to 8.)

*3.* Add this value to the number of decibels of attenuation in the playback system.

The result is a decibel value corresponding to the subject's threshold defined as the level at which he is able to understand 50 per cent of the test sentences. The subject's hearing loss is the difference between this value and the corresponding value for a group of normal hearing subjects.

TABLE 2.

| 1 | 2 | 3 | 1 | 3 | 2 |
|---|---|---|---|---|---|
| Items | Decibel Values | | Items | Decibel Values | |
| Correct | List 1 | Lists 2-8 | Correct | List 1 | Lists 2-8 |
| 4 | 5 | 2 | 16 | 29 | 14 |
| 5 | 7 | 3 | 17 | 31 | 15 |
| 6 | 9 | 4 | 18 | 33 | 16 |
| 7 | 11 | 5 | 19 | 35 | 17 |
| 8 | 13 | 6 | 20 | — | 18 |
| 9 | 15 | 7 | 21 | — | 19 |
| 10 | 17 | 8 | 22 | — | 20 |
| 11 | 19 | 9 | 23 | — | 21 |
| 12 | 21 | 10 | 24 | — | 22 |
| 13 | 23 | 11 | 25 | — | 23 |
| 14 | 25 | 12 | 26 | — | 24 |
| 15 | 27 | 13 | | | |

RECORDING SCRIPT FOR AUDITORY TEST 12:

LIST 1.

| Level | Answer | Question |
|---|---|---|
| 0 db. | B | 1. What letter comes between A and C? |
| | Yes | 2. Do flies have wings? |
| | Monday | 3. What day comes after Sunday? |
| —6 db. | 3 or 4 | 4. How many colors are there in the American Flag? |
| | 11 | 5. What number comes after 10? |
| | Hammer | 6. What tool do you drive nails with? |
| —12 db. | 7 | 7. What number comes between 6 and 8? |
| | Yes | 8. Are moths dangerous to clothing? |
| | February | 9. What month comes after January? |
| —18 db. | 5 | 10. How many pennies are there in a nickel? |
| | No | 11. Is there a lot of water in the desert? |
| | Weak | 12. What is the opposite of strong? |
| —24 db. | 9 | 13. What number comes before 10? |
| | Bullets | 14. Does a gun shoot flowers or bullets? |
| | Old | 15. What is the opposite of new? |
| —30 db. | France | 16. In what country is Paris? |
| | No | 17. Do you climb mountains in a sailboat? |
| | X | 18. What letter comes after W? |
| —36 db. | Tuesday | 19. What day comes after Monday? |
| | Light | 20. What is the opposite of dark? |
| | 12 | 21. What number comes after 11? |

1,000-cycle tone

LIST 2.

| Level | Answer | Question |
|---|---|---|
| 0 db. | Gas | 1. Does a car burn gas or paper? |
| | Leather, Paper | 2. What are books made of? |
| | B | 3. What letter comes after A? |
| | White | 4. What color is snow? |
| —4 db. | Man | 5. Which is larger, a man or a mouse? |
| | White | 6. What is the opposite of black? |
| | 48 | 7. How many states are there in the Union? |
| | A | 8. What letter comes before B? |
| —8 db. | 7 | 9. How many days are there in a week? |
| | Eyes | 10. What do you see with? |
| | Horns | 11. Does a cow have kittens or horns? |
| | Head | 12. Where do you wear a hat? |
| —12 db. | B | 13. What letter comes before C? |
| | Green | 14. What color is spinach? |
| | 4 | 15. What number comes after 3? |
| | Japan | 16. What country is Tokyo in? |
| —16 db. | Monday | 17. What day comes before Tuesday? |
| | 8 | 18. What number comes after 7? |
| | Feet | 19. What part of the body do you put shoes on? |
| | Walk | 20. Does an elephant walk or crawl? |
| —20 db. | Razor | 21. What instrument do you shave with? |
| | Y | 22. What letter comes between X and Z? |
| | No | 23. Can you burn your mouth with ice cream? |
| | Young, New | 24. What is the opposite of old? |

| Level | Answer | Question |
|---|---|---|
| —24 db. | March | 25. What month comes after February? |
| | 10 | 26. How much is 4 and 6? |
| | Yes | 27. Does honey come from bees? |
| | Knife | 28. What do you cut bread with? |

1,000-cycle tone

LIST 3.

| Level | Answer | Question |
|---|---|---|
| 0 db. | Saw | 1. What do you saw wood with? |
| | C | 2. What letter comes after B? |
| | Black | 3. What is the color of coal? |
| | Dog | 4. Which is smaller, a dog or a horse? |
| —4 db. | Black | 5. What is the opposite of white? |
| | Canada | 6. What is the country north of the United States? |
| | 3 | 7. What comes between 2 and 4? |
| | 4 | 8. How many weeks are there in a month? |
| —8 db. | Ears | 9. What do you hear with? |
| | Mice | 10. Does a cat eat bricks or mice? |
| | Key | 11. What do you use to unlock a door? |
| | C | 12. What letter comes before D? |
| —12 db. | Trunk | 13. Do elephants have a hump or a trunk? |
| | Dry | 14. What is the opposite of wet? |
| | 11 | 15. What number comes before 12? |
| | Tuesday | 16. What day comes before Wednesday? |
| —16 db. | 10 | 17. How many pennies are there in a dime? |
| | Leg, Foot | 18. What part of the body do you put a sock on? |
| | Oats | 19. Does a horse eat oats or chickens? |
| | Knife | 20. What do you spread butter with? |
| —20 db. | 1 | 21. What number comes before 2? |
| | Red | 22. What color is ketchup? |
| | Old | 23. What is the opposite of young? |
| | April | 24. What month comes after March? |
| —24 db. | America, U.S. | 25. In what country is New York? |
| | Wings | 26. Does an eagle have wings or arms? |
| | 11 | 27. What number comes before 12? |
| | 2 | 28. How many wheels does a bicycle have? |

1,000-cycle tone

LIST 4.

| Level | Answer | Question |
|---|---|---|
| 0 db. | D | 1. What letter comes after C? |
| | Broad, Wide | 2. What is the opposite of narrow? |
| | Mountain | 3. Which is higher, a hill or a mountain? |
| | Short | 4. What is the opposite of tall? |
| —4 db. | Atlantic | 5. What is the ocean east of the United States? |
| | Wednesday | 6. What day comes after Tuesday? |
| | 12 | 7. How many months are there in a year? |
| | 6 | 8. What number comes after 5? |
| —8 db. | Hat | 9. Does a man wear a hat or a table? |
| | Axe | 10. What do you chop wood with? |
| | D | 11. What letter comes before E? |
| | Yellow | 12. What is the color of butter? |

| Level | Answer | Question |
|---|---|---|
| —12 db. | Wet | 13. What is the opposite of dry? |
| | Friday | 14. What day comes after Thursday? |
| | Russia | 15. What country is Moscow in? |
| | 4 | 16. How many quarters are there in a dollar? |
| —16 db. | C | 17. What letter comes after B? |
| | 5 | 18. How many toes are there on each foot? |
| | Calendar | 19. What do you tell the date by? |
| | 2 | 20. What number comes before 3? |
| —20 db. | Hate | 21. What is the opposite of love? |
| | Green | 22. What color is the cloth on a pool table? |
| | July | 23. What month comes after June? |
| | 9 | 24. How much is 1 and 8? |
| —24 db. | Egg | 25. Does an owl lay books or an egg? |
| | Airplane | 26. In what do you fly across a mountain? |
| | 19 | 27. What number comes before 20? |
| | No | 28. Do palm trees grow in Alaska? |

1,000-cycle tone

LIST 5.

| Level | Answer | Question |
|---|---|---|
| 0 db. | Night | 1. Which is darker, night or day? |
| | Pen | 2. Do you write with a chair or a pen? |
| | E | 3. What letter comes after D? |
| | Long, Tall | 4. What is the opposite of short? |
| —4 db. | Red | 5. What is the color of blood? |
| | 24 | 6. How many hours are there in a day? |
| | Pacific | 7. What is the ocean west of the United States? |
| | Thursday | 8. What day comes after Wednesday? |
| —8 db. | Tongue | 9. What does a cat lick with? |
| | Cord, String | 10. What do you tie a package with? |
| | Fish | 11. Does a cat eat fish or straw? |
| | N | 12. What is the first letter in "never"? |
| —12 db. | Bottom | 13. What is the opposite of top? |
| | Hay | 14. Does a cow eat hay or stones? |
| | Sour | 15. Is a lemon sour or salty? |
| | 20 | 16. What number comes between 19 and 21? |
| —16 db. | Ugly, Homely | 17. What is the opposite of pretty? |
| | White | 18. What color is a ping pong ball? |
| | 13 | 19. What number comes between 12 and 14? |
| | Pacific | 20. In what ocean is Pearl Harbor? |
| —20 db. | Thursday | 21. What day comes before Friday? |
| | Glass | 22. What are windows made of? |
| | Sun | 23. What shines in the sky in the daytime? |
| | White | 24. Is a polar bear white or green? |
| —24 db. | 6 | 25. What number comes between 5 and 7? |
| | 2 | 26. How many legs does a man have? |
| | 60 | 27. How many seconds in a minute? |
| | No | 28. Do fish swim in trees? |

1,000-cycle tone

LIST 6.

| Level | Answer | Question |
|---|---|---|
| 0 db. | Friday | 1. What day comes after Thursday? |
| | F | 2. What letter comes after E? |
| | Glass | 3. Do you drink out of a glass or a boot? |
| | Thin | 4. What is the opposite of fat? |
| —4 db. | White | 5. What color is milk? |
| | 60 | 6. How many minutes in an hour? |
| | U.S. | 7. What country is north of Mexico? |
| | Teeth | 8. What do you chew with? |
| —8db. | Match | 9. What do you light a fire with? |
| | 7 | 10. Which is more, 7 or 4? |
| | Friday | 11. What day comes before Saturday? |
| | Y | 12. What letter comes before Z? |
| —12 db. | Top | 13. What is the opposite of bottom? |
| | Fur | 14. Does a cat have fur or feathers? |
| | Pink, Red | 15. What color is the tongue? |
| | 2 | 16. How many eyes does a man have? |
| —16 db. | America, U.S. | 17. In what country is the Mississippi River? |
| | 1 | 18. How many nails are there on each finger? |
| | Stars, Moon | 19. What shines in the sky at night? |
| | 3 | 20. What number comes before 4? |
| —20 db. | Tame | 21. What is the opposite of wild? |
| | Yes | 22. Does a giraffe have a longer neck than a frog? |
| | 12 | 23. What number comes between 11 and 13? |
| | Bow | 24. What do you shoot arrows with? |
| —24 db. | 19 | 25. How much are 9 and 10? |
| | Wild | 26. What is the opposite of tame? |
| | No | 27. Are shoes made of stone? |
| | 3 | 28. What number comes after 2? |
| | | 1,000-cycle tone |

LIST 7.

| Level | Answer | Question |
|---|---|---|
| 0 db. | Bed | 1. Do you sleep in a bucket or a bed? |
| | 5 | 2. What number comes before 6? |
| | Yes | 3. Does a spider make a web? |
| | Sunday | 4. What day comes before Monday? |
| —4 db. | 5 | 5. What number comes after 4? |
| | White | 6. What color are teeth? |
| | Thin, Narrow | 7. What is the opposite of wide? |
| | 3 | 8. How many feet are there in a yard? |
| —8 db. | 4 | 9. What number comes between 3 and 5? |
| | White | 10. What color is a polar bear? |
| | England | 11 In what country is London? |
| | Head | 12. What part of the body do you put a hat on? |
| —12 db. | Cold | 13. What is the opposite of hot? |
| | Yes | 14. Are storms dangerous to shipping? |
| | December | 15. What month does Christmas come in? |
| | 5 | 16. What number comes between 4 and 6? |

| Level | Answer | Question |
|---|---|---|
| —16 db. | Chalk | 17. What do you write on a blackboard with? |
| | Car | 18. Do you drive in a house or a car? |
| | Germany | 19. In what country is Berlin? |
| | Tail | 20. Does a horse have horns or a tail? |
| —20 db. | Nose | 21. What do you smell with? |
| | 5 | 22. How much is 2 and 3? |
| | 7 | 23. What number comes before 8? |
| | Feet | 24. What part of the body do you put shoes on? |
| —24 db. | Pretty, Beautiful | 25. What is the opposite of ugly? |
| | No | 26. Do we have lightning in a snow storm? |
| | 14 | 27. What number comes after 13? |
| | Saturday | 28. What day comes before Sunday? |

1,000-cycle tone

LIST 8.

| Level | Answer | Question |
|---|---|---|
| 0 db. | America, U.S. | 1. In what country is Chicago? |
| | Z | 2. What letter comes after Y? |
| | Green | 3. What is the color of grass? |
| | 6 | 4. What number comes before 7? |
| —4 db. | Fingers, Hand | 5. What part of the body do you write with? |
| | Water | 6. What comes out of a kitchen faucet? |
| | 9 | 7. What number is between 8 and 10? |
| | Water | 8. Which is wetter, water or sand? |
| —8 db. | Shovel | 9. Do you dig holes with a shovel or a rake? |
| | Yellow | 10. What is the color of a lemon? |
| | Sunday | 11. What day comes after Saturday? |
| | Land | 12. Does a lion live in water or on land? |
| —12 db. | January | 13. What is the first month of the year? |
| | Black | 14. What color is a crow? |
| | Clean | 15. What is the opposite of dirty? |
| | Hair | 16. What grows on top of your head? |
| —16 db. | Bat | 17. What do you hit a baseball with? |
| | No | 18. Do you get beef from a chicken? |
| | 8 | 19. What number comes between 7 and 9? |
| | Eyes | 20. What do your eyelids cover? |
| —20 db. | Rails | 21. Do trains run on rails or water? |
| | Warm, Hot | 22. What is the opposite of cold? |
| | None, 2 | 23. How many horns does a cow have. |
| | December | 24. What is the last month of the year? |
| —24 db. | N | 25. What letter comes between M and O? |
| | White | 26. What color is salt? |
| | 12 | 27. How many inches in a foot? |
| | 21 | 28. What number comes after 20? |

1,000-cycle tone

# WHAT WE CAN DO FOR OUR TRACHEOTOMIZED PATIENTS.*

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Every laryngologist has among his patients a number who have to use a tracheotomy tube permanently. For the most part, these patients have been operated upon for goiter, resulting in a bilateral injury to the recurrent nerve. Several of these patients can eventually be freed of the tube since the function of the vocal cords may be restored if there is only a partial injury to the nerve; nevertheless, to induce a patient to wear a tracheotomy tube is always a problem for the doctor. Even the successes of the Kelly-King operation, which, with certain modifications, is being more and more employed, can do little to alter this. The number of tracheotomy tube users is rather on the increase. Tracheotomy is often necessary conjointly with X-ray treatment in the case of malignant diseases of the larynx, and total laryngectomy, an operation which is extremely promising during the early stages of cancer, is being done more frequently. These patients especially need the conscientious care of the laryngologist. Their entire future depends upon his experience, his ability and his devotion. For this reason, their supervision is one of the most gratifying missions of a doctor.

The treatment starts with tracheotomy. The trachea should not be slit lengthwise, though, unfortunately, this is often done, but should be opened by the excision of a circular piece from the tracheal wall, the size of the selected tube. By this means, favorable healing conditions are created and the undesirable formation of granulation and scars is prevented. It is self-evident that the tracheal incision should be as low as possible in the case of patients who are to be submitted to

*From the Otolaryngological Department of the University of Zurich; Director: Prof. Dr. F. R. Nager.

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radium or X-ray treatment of the larynx, in order to avoid the secondary rays. Also, in other cases a low incision of the trachea is advocated to prevent edema and scar stenosis in the region of the glottis.

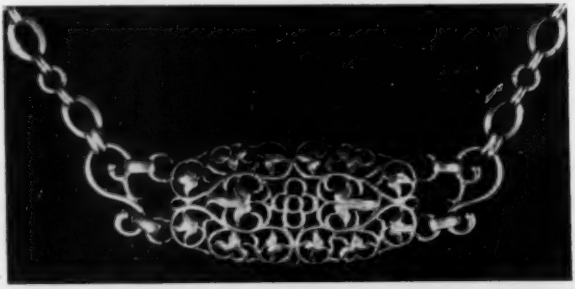

Fig. 1a.

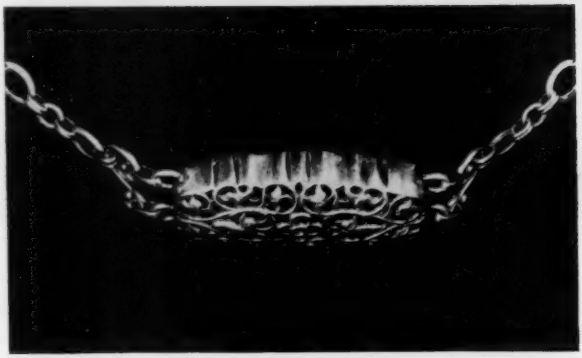

Fig. 1b.

Fig. 1. Front and close-up photograph of a brooch.

Only the most scrupulous hygiene on the part of the doctor and the nurse during the postoperative treatment of the patient can lead to the quickest and best healing results. Perfect breathing conditions, a small amount of secretion and a minimal urge for coughing are guaranteed by preventing any growth of granulation through regular control of the

wound and by proper selection of shape and size of the tube. The speaking tube should be fitted so as to prevent any pressure by the distal end on the anterior wall of the trachea. The opening made at the convex bend should coincide exactly with the lumen of the trachea.

The tubes employed by us are double channeled. The inner tube can be easily removed and cleaned by the patient himself. Care must be taken that the length of this tube corresponds exactly with that of the outer one. Only in this way serious

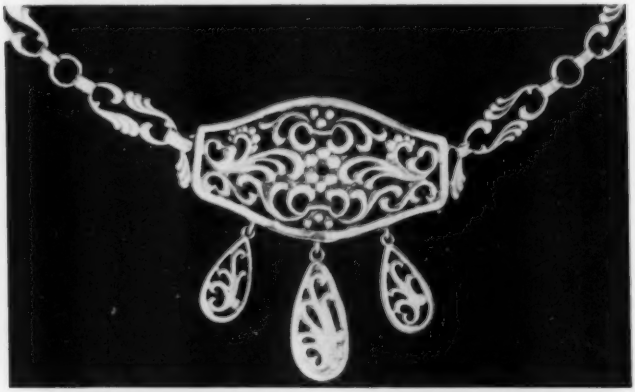

Fig. 2. Close-up photograph of a brooch and chain.

dyspneic conditions caused by the collection of secretion at the distal end can be prevented. The head of the tube is shaped as flatly as possible to lie close against the neck. It contains a valve which opens with inhaling and closes when exhaling and which, when necessary, can be removed and controlled by the patient himself.

Conscientious care of the tracheostoma permits the patient in relatively short time to adjust himself to the tube and to the change of breathing required by it. For this reason, the full reattainment of working power depends to a great extent upon the ability of the doctor. There are only few occupa-

tions, the exercise of which is rendered impossible through the use of a tube, and which would necessitate retaining (nursing personnel, work in dusty conditions, etc.), but disfigurement often results in serious psychic trauma in spite of general well-being, particularly in the case of younger persons

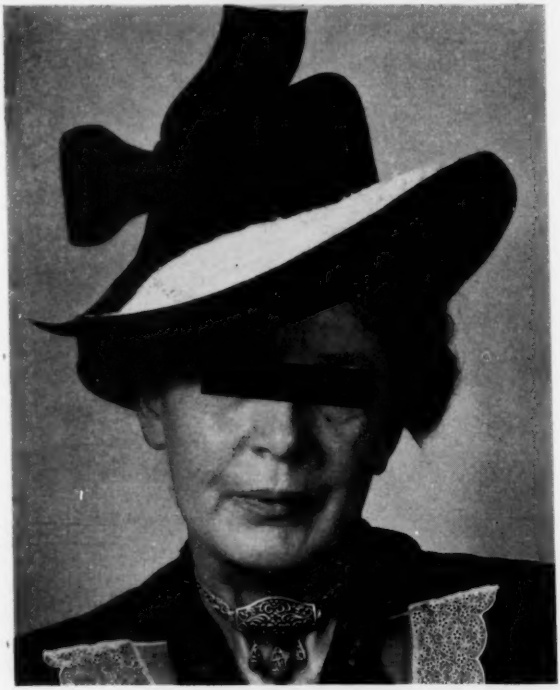

Fig. 3.
Figs. 3 and 4. Views of brooches when worn.

and female patients. It may be for this reason that the newer operations of widening the glottis have met with such approval, despite the risk of deterioration of the voice. Women particularly suffer from this disfigurement alone. The wearing of a tube can often be concealed through clever selection of apparel. Since, however, in most cases an adapta-

tion of the clothing is rather apparent, particularly with young women, we have had brooches of precious metals made by our goldsmith to conceal the tube; the suggestion of one of our patients. They are fastened by a clever contraption to

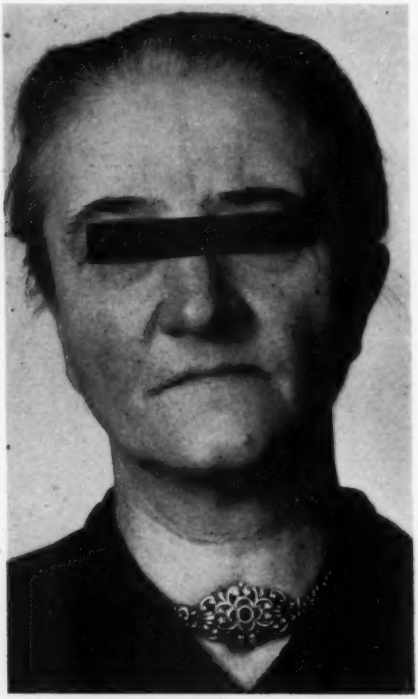

Fig. 4.

the head of the tube, are worn on a chain around the neck, and may even conceal the scar of the goiter operation. Several of our patients are extremely satisfied with this solution and have by this means rid themselves of social inhibitions from which they and their relatives suffered. The illustrations show design, construction and the effect when wearing such brooches.

# A METHOD OF OBTAINING SECRETIONS FROM NASOPHARYNX FOR DIAGNOSIS OF NASAL ALLERGY

## (PARTICULARLY USEFUL IN DRY NOSES).

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Hansel's classical method of obtaining nasal secretions for the microscopic examination for eosinophil content has been of inestimable value. This method is to have the patient blow his nose on a piece of wax paper and then transplant the mucus from the paper to a glass slide. The mucus is then dried and stained with Hansel's quick polychrome stain. This gives a simple, quick and almost sure method for diagnosing nasal allergy in patients who have plenty of nasal discharge. The entire credit for this work goes to Dr. French K. Hansel, of St. Louis.

Many chronic allergic noses, however, are very dry, and it may be difficult to get a good nasal smear. Quite often about all that can be obtained, on blowing the nose, are epithelial cells, hence we have attempted other methods for obtaining the secretions.

The nasopharynx is the natural physiological reservoir for nasal secretions. It is the nasopharynx that furnishes the logical spot for good specimens of mucus. We suggest one of the following procedures in order to obtain this mucus:

1. Depress the tongue with a tongue blade and with a pair of bayonet forceps push up the soft palate and pick off a bit of mucus from the posterior nasopharyngeal wall.

2. Use a metal suction tube with a thumb hole for starting and stopping suction. With suction on, and thumb on thumb hole, place the suction tube along the floor of

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the nose until the end touches the posterior wall of the nasopharynx (see Fig. 1). As soon as you can hear the mucus enter the suction tube, remove the thumb from the thumb hole and then remove the tube from the nose. The suction tube will usually contain a good specimen of mucus. Disconnect the metal tube from the rubber tubing (see Fig. 2), and then with the thumb replaced over the thumb hole, blow the mucus out onto a glass slide (see Fig. 3).

Fig. 1.

Figs. 2 and 3.

*3.* Use the same suction method except depress the tongue with a tongue blade, and with the suction tube lifting the soft palate and touching the posterior wall of the nasopharynx, aspirate a little mucus. (Continue as in No. 2.)

The aspiration method, through the nose, has been particularly good in obtaining good smears. We find that quite often in dry, stuffy, allergic noses the nasopharyngeal smear will be positive for eosinophils when the anterior nasal smear will be negative. We recommend this method as being simple, quick and highly satisfactory.